

THE POPULAR SCIENCE MONTHLY

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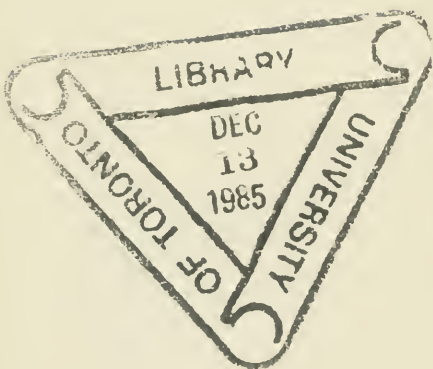
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THE POPULAR SCIENCE MONTHLY

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WHAT WE OWE TO AGASSIZ¹

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THIS day, one hundred years ago, was born in Switzerland a man-child destined to astonish and uplift the world. Christened Jean Louis Rodolphe, he was and is known as Louis Agassiz, or simply Agassiz, his eminent son being distinguished as Alexander.

Why is this centennial celebrated here and elsewhere? Rather, by such as know what Agassiz was, what he did, and what he tried to do, would it be asked, Why is not this day observed in all lands, by all classes, yea, even in behalf of animals, plants, the rocks and the very elements?

For, from a child, Agassiz loved nature and humanity. The one he strove to interpret, the other to cheer and enlighten. He was a naturalist in the broadest sense, a sense broader than is possible in these days. His thirst for knowledge was equaled only by his desire to impart it, and his ability to earn money was surpassed only by his determination to spend it for the welfare of man and the glory of God.

More or less complete accounts of Agassiz have been published in various books and periodicals. A partial list of these is included. By far the best, although lacking many desirable details and restricted by the relationship, is the "Life and Correspondence" by his wife. My admiration for this grows with each re-reading. In respect to both subject and style it might well be included among the entrance requirements in English. It portrays an eminent scholar, indefatigable collector and teacher, sincere patriot, staunch friend and fascinating personality in a manner so just, so vivid and inspiring that, were it practicable, in place of the many spoken observances of this centenary, I

¹ Address at the Centenary of Louis Agassiz delivered, at the request of President J. G. Schurman, in Barnes Hall, Cornell University, May 28, 1907.

could wish that the coming Memorial Day might be partly devoted to its perusal—*out-of-doors*—by every man, woman and child.²

In enumerating the grounds upon which this commemoration might be well-nigh cosmic in its scope, so far as possible I shall use the words of Agassiz himself or of others fitly representing the several groups.

The following account of the "Glacial Theory" is condensed from the address³ at the unveiling of the Agassiz tablet in our Memorial Chapel, June 17, 1885, by the geologist and paleontologist, Professor J. S. Newberry:

"In 1837 the Association of Swiss Naturalists met at Neufchatel, and Agassiz then advanced the theory of a general glacial epoch of which he may justly be called the author. At first it met with violent opposition [Marcou says, p. 108, 'it was like a pistol-shot fired into the midst of the assembly'], but this only stimulated those who had adopted it to greater enthusiasm in their researches. . . . One of the motives which led Agassiz to America was his ardent desire to see for himself whether the glacial record was the same for the New as for the Old World. . . . Many years before his death he had the satisfaction of knowing that his theory was applicable to the whole northern hemisphere, and the pleasure of studying a similar record in southern South America." I wish there were time to quote from Mrs. Agassiz's volume (pp. 317-332) the graphic, indeed thrilling, story of his life upon the glaciers. He once caused himself to be lowered into a crevasse to the depth of one hundred and twenty-five feet, when death would have attended either the fraying of the rope by sharp edges of ice or the dislodgement of the huge stalactites between which he had to steer his way.

Agassiz was a well-informed botanist. His "Lake Superior" and "A Journey in Brazil" deal largely with vegetation; two or three smaller papers are botanic, and one of the courses before the Lowell Institute was, he told me, upon trees and plants.⁴ A member of the administrative staff of our College of Agriculture related to me the following incident: During Agassiz's stay here in 1868 he often walked about the then very open campus. She and her brother, little children, conceived a great admiration for him, called him "our Frenchman," and used to offer him flowers. On one occasion she was about to pluck a red clover upon which a bumblebee had just alighted.

² The only other comparable biography is the "Life, Letters and Works" by Marcou, and it will be quoted frequently. Its peculiarities are well stated in *The Nation* for May 7, 1896. In a letter to me, dated March 21, 1896, he expresses his regret at the inadvertent omission of "some of the best" from the enumeration of Agassiz's pupils and assistants.

³ As printed in the "Proceedings in memory of Louis Agassiz and in honor of Hiram Sibley," pp. 11-12.

⁴ May this be that which was given in 1853 under the title, "Natural History"?

He restrained her, saying gently, "Do not frighten it away; the bees are the friends of the flowers."⁵

Agassiz's concern for the promotion of agriculture was evinced by word and deed upon many occasions.⁶ In 1861 he supervised the drawings for the "New Edition" of Harris's "Insects injurious to vegetation," and "rendered assistance by way of suggestion and advice throughout" the publication of the work that was the prototype of the later extensive reports and organizations, state and national, in the line of economic entomology. The last chapter of "A Journey in Brazil," published in 1868, was more than half devoted to the agriculture and forestry of that country.

So deeply interested was Agassiz in the problems involved in the improvement of domesticated animals that, at the close of his exhausting summer at Penikese, and only three months before his death, he wrote me a letter of 1,700-1,800 words devoted mainly to that subject. The following sentences are very suggestive:

We naturalists can not afford the expense necessary for making the investigations and answering the questions about which farmers universally expect us to be prepared to give information. It would cost hundreds of thousands of dollars to study the embryology of the horse as I have studied that of the snapping-turtle. But turtle eggs can be had for the asking, while every egg and every embryo of the higher animals will cost the price of a mare or a cow, and so for other species. I do not know one scientific man in the world so placed that he could kill one hundred of these animals a year, for a number of successive years in order to study their embryology; and yet until this is done we shall go on groping in the dark as far as any real improvements in the breeding of stock are concerned.

It is probable that this topic occupied him in his last public effort, a lecture on "The Structural Growth of Domesticated Animals" before the Massachusetts State Board of Agriculture, only twelve days before his death.

On the twenty-eighth of May, 1874, the birthday of Agassiz next following his death, there was held here a Memorial Meeting.⁷ It was addressed, among others, by the Hon. John Stanton Gould, then our non-resident lecturer on agriculture, who had witnessed interviews between Agassiz and farmers seeking information as to animals, crops and soils. He said "It was beautiful to see that illustrious man impart the needed facts in language perfectly adapted to the intellectual and scientific status of the inquirer."

⁵ See, also, the relation of a botanist, Professor C. F. Millspaugh, *Cornell Era*, June, 1907, p. 443, and "Proceedings of the Memorial Meeting of the Cambridge Historical Society," May 27, 1907.

⁶ It is not easy to account for the omission of entries like *agriculture* and *farmer* from the indexes of the volumes by Marcou and Mrs. Agassiz.

⁷ It was for the purpose of raising a sum to be added to the "Teachers and Pupils' Fund" in support of a scholarship at the Museum. There was raised \$100, of which about one fourth was given by President White.

How clearly the situation was recognized by Agassiz himself is shown in the following paragraph from the preface to his "Contributions to the Natural History of the United States":

There is not here [as in Europe] a class of learned men, distinct from the other cultivated members of the community. On the contrary, so general is the desire for knowledge, that I expect to see my book read by operatives, by fishermen, by farmers, quite as extensively as by the students in our colleges or by the learned professions, and it is but proper that I should endeavor to make myself understood by all.

For the means of carrying on the regular work of the museum, and for such special projects as are referred to above, Agassiz depended largely upon grants from the state legislature as recommended by the board of education. Many of the legislators were farmers or from agricultural districts, so that his efforts to improve the quality of domesticated animals and to check the ravages of insects were both natural and politic.

But it may well be doubted whether even the weighty facts and arguments at his disposal would have sufficed without the extraordinary influence of his personality and eloquence. This was alluded to by Oliver Wendell Holmes⁸ in the sentence, "The hard-featured country representatives flocked about him as the fishes gathered to hear Saint Antony, as the birds flocked to hear the sermons of Saint Francis." It has been more fully described by Thomas Wentworth Higginson and Charles Mellen Tyler.⁹ With the latter's permission I will quote it in advance, nearly *verbatim*:

In 1861-2 I was in the Massachusetts Legislature and a member of the Committee on Education before which Professor Agassiz appeared to secure the annual appropriation for his museum. It was the year of the storming of Fort Sumter, of the attack upon a Massachusetts regiment passing through Baltimore, and of the first battle of Bull Run. Members of both houses of the Legislature foresaw a prolonged and bloody conflict, a great demand upon the Treasury, an increased and burdensome taxation to maintain the forces in the field. Our hearts were not high; we cut and slashed all bills of appropriation, and scrutinized with microscopic suspicion every bill of either house which looked to any increase of expenditure. Our committee anticipated the interview with Agassiz with some impatience and in a negative disposition of mind. We had, in fact, resolved beforehand not to recommend to the House and Senate the usual gift from the State. But when Agassiz appeared before us with his delightful accent and bland, persuasive, almost affectionate personal appeal to each of us, we wholly forgot the distress of the nation, the probable rejection of our recommendation by the two houses, and went over to Agassiz, horse, foot and dragoons, reported a bill for the usual outlay for his benefit, and to our surprise we carried it through.

⁸ In the letter declining the invitation to attend the unveiling of the Agassiz tablet, p. 7 of the "Proceedings" mentioned above.

⁹ The former in the *Boston Transcript* for April 23, 1907, and the latter in the *Harvard Graduates' Magazine* for June, 1907, p. 778.

Agassiz was born near Lake Neufchâtel in the region known as the Seeland of Berne. His early home was literally surrounded by lakes, rivers and marshes. "Almost as soon as he was able to move alone he took to water like a young duck. All the fishermen became at once very fond of the little fellow, and there was a friendly rivalry among them to get him into their boats and show him how to catch fish."¹⁰

This friendly relation with the takers of fish was maintained throughout his life. Wherever he went he visited the markets and ascertained who were the most enterprising and intelligent purveyors. From them he gained not merely specimens but information, and to them he imparted his own knowledge in appropriate terms. One of his closest friends was Captain N. E. Atwood, of Provincetown, Mass., whose personal knowledge of marine fish and fisheries was so highly estimated by Agassiz that, upon the latter's suggestion, he was invited to give a course of lectures before the Lowell Institute.

In 1853 he issued a circular asking for collections of fishes from various fresh-water systems of the United States. . . . To this he had hundreds of answers, many of them very shrewd and observing. . . . A great number and variety of collections . . . were forwarded. As to the marine forms, "many a New England captain, when he started on a cruise, had on board collecting cans,"¹¹ furnished by Agassiz, to be filled . . . and returned." (Mrs. Agassiz, pp. 518-519.)

The participation of women in any memorial of Agassiz is most natural. His mother was his most intimate friend and his letters to her from America are simply delightful. At the museum his lectures were open to women as well as men. He had great sympathy with the desire of women for larger and more various fields of study and work, and a certain number, including the librarian, have always been employed as assistants. For eight years (1855-63) he lectured almost daily in a school conducted by his wife; and upon her intellectual companionship and cooperation he became so dependent that he once declared to me, with signs of deep emotion, "Without her I could not exist." Never from his lips did I hear a word that might not have been spoken in her presence.

In 1873, of the forty-four teachers admitted by him as pupils at the Penikese school, sixteen—more than one third—were women. Coeducation—then hotly debated and regarded by some as a bugbear—had not with him even the dignity of existence as a problem. He declared that he had "no hesitation from the start." His attitude was certainly consistent; among the theses defended at his graduation in 1830 one was entitled *Femina humana mari superior*. Are some male members of this university concerned lest that phrase become the appropriate motto for the College of Arts and Sciences?

¹⁰ Marcou, I., pp. 7-8.

¹¹ One of these cans arrived at Penikese during the last summer of his life, and I well recall the interest, akin to that in a Christmas box, with which Agassiz and his assistants and pupils drew forth the contents.

Before me are representatives of the African race, members of the university in full enjoyment of all its educational advantages. Fitly may they unite in honoring the memory of one who so effectively aided the establishment of this cosmopolitan institution. For, whatever may have been Agassiz's technical views as to the diversity of origin of the so-called human races, and however he may have deprecated amalgamation and the premature conferring of certain political privileges, his correspondence with Dr. Samuel G. Howe leaves no doubt as to his position upon the fundamental issue :

The negroes should be equal to other men before the law. . . . They are entitled to their freedom, to the regulation of their own destiny, to the enjoyment of their life, of their earnings, of their family circle. . . . It is one of our primary obligations to remove every obstacle that may retard their highest development.

One of Agassiz's two daughters married Quincy A., brother to Robert Gould Shaw, commander of the "Fifty-fourth," the first of the two Massachusetts colored regiments in the Civil War. On the eighteenth of July, 1863, Colonel Shaw fell at Fort Wagner and was there buried with his dusky followers. So far from regretting the circumstances of his death or the nature of his last resting-place, the hero's name has been repeated in the second generation.

By none should the memory of Agassiz be cherished more devoutly than by the science teachers of America. I refer here not so much to the favored few¹² who enjoyed his direct instruction whose office is so finely drawn in these lines by James Russell Lowell:

He was a Teacher; why be grieved for him
Whose living word still stimulates the air?
In endless file shall loving scholars come,
The glow of his transmitted touch to share.

From highest to lowest, every teacher of natural science in this country is indebted to Agassiz for improvements in methods, for elevation of public respect, and for increase in compensation.

Upon the point last named Agassiz had cause for entertaining decided views. For years his regular salary was only \$1,500; indeed, not until the very end did a gift relieve him entirely from the necessity for outside labors which doubtless shortened his days. His last letter to me, dated November 25, 1873, contained the following significant sentence: "If scientific men are ever to be placed on a proper footing of independence in this country, it is for the younger to work for it. They have a fine opportunity of doing it by pointing out what the older men have done on a starving allowance." On an earlier occasion he declared

¹² For example, A. C. Apgar, of Trenton; W. O. Crosby, of Boston; W. K. Brooks, of the Johns Hopkins; David S. Jordan, of Stanford; C. S. Minot and W. H. Niles, of Boston; T. B. Stowell, of Potsdam, N. Y.; C. O. Whitman, of Chicago, and A. E. Verrill, of Yale.

that thereafter he would not give a public lecture for less than \$500, in order to let those who held the purse-strings appreciate the value of such services.¹³ While he did not hesitate to accept for the museum, at a low remuneration, or even with none, the services of young men who desired at the same time to learn from him or to enjoy opportunities for research, my personal experience with him during four years and one summer warrants me in saying that in cases of a different sort he was liberal and even generous.

At the middle of the last century American naturalists were few, scattered and little understood. Commonly their vocation was medicine, and their botanic and zoologic avocations were rather condoned than commended. The prevailing notions are embodied in this anecdote: A few years after his arrival in America Agassiz made one of a small party of Harvard professors who traversed the White Mountain region in a carriage driven by a countryman. Three of them were vivacious, restless, and on the lookout for specimens. They would call a halt; leap from the vehicle before it stopped; dash over the fields, and return with prizes in their boxes, in their hands and pockets, and even pinned upon their hats. The fourth, Professor Felton, the brother-in-law of Agassiz, sat quietly in his corner reading a favorite Greek author. When the bewildered driver could stand it no longer he elicited from Felton information which led him to view the behavior of the others with compassionate toleration. His interpretation was thus conveyed to the innkeeper at the close of the day: "I drove the queerest lot you ever saw. They chattered like monkeys. They wouldn't keep still. They jumped the fences, tore about the fields, and came back with their hats covered with bugs. I asked their keeper what ailed them; he said they was *naturals*, and judgin' from the way they acted I should say they was."

Before long, however, in and about Cambridge and wherever Agassiz remained for any time, he and those inspired by him made the pursuit of natural history not only familiar and reputable, but almost fashionable. Yet when this university opened the collecting of specimens was so unusual that the following incident is related to me by Winfield Scott Merrill, who was here in 1868-9:

While walking in the country I saw a boy holding a horse, and he told me it belonged to a "crazy Dutchman" over in the woods looking for birds' nests.¹⁴

In an article, "Louis Agassiz, Teacher,"¹⁵ his ideas and practise as to methods of teaching are considered by me at some length. On the present occasion I quote from E. L. Youmans, late editor of the *POPULAR SCIENCE MONTHLY*:

¹³ This was said to Professor Wyman in my presence, November 17, 1866.

¹⁴ This was printed in the *Cornell Era* of the period, but by some it was regarded as a myth.

¹⁵ In the June number of the *Harvard Graduates' Magazine*.



Agassiz had a profound interest in popular education, but the soul of that interest was for improvement in its methods. In the matter of public instruction he was a revolutionist and a propagandist. He warred with current ideas and consecrated practises. He condemned in the most emphatic way the wretched lesson-learning routine that prevails in the schools. . . . He never wearied in the endeavor to propagate more rational opinions, and we can not doubt that the seed thus sown will yet ripen into most valuable fruit. He denounced our wordy and bookish education as baseless and unreal, and demanded such a change in our system of instruction as shall bring the pupils face to face with nature herself, and call out the mind by direct exercise upon phenomena—the facts, laws, relations and realities of the world of experience.

The abundance of this educational fruit is indicated by Liberty H. Bailey, an exponent alike of “nature-study teaching” and of “science-teaching for science’ sake”:

Agassiz gave us the motto, “Study nature, not books.” He taught the study of nature by the natural method. . . . And, although his teaching may not have been nature-study, as we understand the term—being given from the investigator’s or the specialist’s view-point, and intended primarily for students and adults—the present nature-study movement undoubtedly is a proximate result of the forces that he set in motion. (“The Nature-study Idea,” pp. 5, 6, 8.)

Summer schools and biologic stations are now so common at the seashore and by inland waters that those who attend them for instruction or research do not always realize their origin with Agassiz, thirty-five years ago in the establishment of “The Anderson School of Natural History at Penikese Island.” Its history is given in the report of the trustees, and various aspects of it have been presented in the publications enumerated in my article, “Agassiz at Penikese.”¹⁶ The first session was directed by Agassiz himself, in the last summer of his life; the second by his son. “Although,” to quote Mrs. Agassiz (p. 772), “the Penikese school may be said to have died with its master, it lives anew in many a seaside laboratory organized upon the same plan.”

Our proneness to forget the pioneers by whose ideas and labors we profit was noted by Agassiz himself in his Humboldt Address (pp. 5, 6):

The fertilizing power of a great mind is truly wonderful; but as we travel farther from the source, it is hidden from us by the very abundance and productiveness it has caused.

Particularly should this day be remembered by that apparently diminishing number of collegiate teachers who hold that the kingdom of scholarship cometh not with observation nor with the assumption of millinery. In this country Agassiz wore no decorative ribbon of any kind, although he possessed that of the Red Eagle of Prussia and that of the French Legion of Honor. Although impressive in aspect and dignified in manner, he was extremely simple and unpretending in his ways, and did not like to make an appearance different from that of ordinary people in his neighborhood. He was of a joyous disposition

¹⁶ *American Naturalist*, March, 1898.

and upon occasion he could be merry as a child. But for his merri-ment time and place must be fitting; *Dulce est desipere in loco*. He upheld the dignity of scholarship, and regarded university property and university time as consecrated to the loftiest functions.

Agassiz has not generally been thought of as a disciplinarian; yet a single incident would justify the celebration of this day by those who regard the saying, "Boys will be boys," as inapplicable beyond the secondary school. Early in the summer at Penikese three young men committed a breach of decorum which some might consider amusing. The next morning Agassiz simply announced that they had shown themselves undeserving and would leave the island before noon.

To the public Agassiz was best known through his lectures before the Lowell Institute and elsewhere, and by the "Methods of Study in Natural History." But an enormous amount of technical work is represented by his European publications, by the four volumes of the "Contributions to the Natural History of the United States," and by his papers of greater or less length upon many zoologic topics. Marcou enumerates 425 titles. Coues thinks¹⁷

the greatest practical boon he ever conferred upon working naturalists was his "Nomenclator Zoologicus," with its accompanying index—the veriest drudgery imaginable for an author, yet drudgery of a kind that no hack or mere compiler could have performed; and only those who have to keep it at their elbows can be sufficiently grateful for this instrument.

But working zoologists, anatomists and chemists are indebted to Agassiz for another practical service which probably could not have been rendered so efficiently by any other human being, *viz.*, the remission, by act of congress, of the tax upon alcohol used for scientific purposes. Alcohol is consumed largely in chemical laboratories, and it was nearly the only museum preservative in use before the comparatively recent introduction of formal. Representations to congress were made by Spencer F. Baird and others concerned, but it is doubtful if they would have succeeded without the exercise of Agassiz's commingled powers of conviction and persuasion.

No native scientist did more than Agassiz to establish and maintain the intellectual independence of his adopted country.¹⁸ Aside from his published works, his training of young men, his founding of the museum and his provision of means for employment and research that might otherwise have been sought abroad, upon at least two occasions he urged such cultivation of science in this country as should free American naturalists from the necessity of looking up to Europeans as their leaders and guides.

At the annual meeting of the Boston Society of Natural History,

¹⁷ Review of "Marcou" in *The Nation*, May 7, 1896.

¹⁸ Unconsciously I have used here nearly the words of Oliver Wendell Holmes in his letter referred to above.

May 17, 1848, "he made a most earnest and stirring appeal" in that direction. Three years later he made a declaration of sentiment and policy, emphatic, specific and self-sacrificing. This shall be given in his own words:¹⁹

Twenty years ago I was present at a meeting of the American Association for the Advancement of Science, held in Cincinnati, where specimens from all parts of the west were brought together to be seen by the scientific men of the east. . . . When one of the members of the association moved that to make the best use of these collections they should be sent to Europe to be identified by paleontologists and zoologists of the old world, I opposed that motion as earnestly as I could, stating that it would be an acknowledgment of inferiority on the part of America from which we could never rise again. . . . My motion was carried, and yet I remained under the imputation, which was loudly expressed by some, that I had carried a big job; that my motion had been made in order that I might have the benefit of describing those specimens, and thus raise my reputation. I resolved then to myself, but never spoke of it before, that I would never describe an American fossil, and I have kept my resolve. The progress since then has been such that now an American student scouts the idea of sending a piece of work to a European ordeal.

Agassiz came to America upon a scientific mission provided for by the King of Prussia. He found here unlimited material for research, the chance of earning by lecturing the means of repaying obligations incurred by his European publications, and a cordial welcome alike from naturalists, from society and from the people at large. Changed political conditions rendered his return less desirable, and he accepted a professorship in the newly-established Lawrence Scientific School at Harvard University.²⁰ Ten years later he declined a favorable and repeated offer of a chair in the Paris Museum of Natural History. When the Civil War broke out "no American cared more than he for the preservation of the Union and the institutions it represented." Indeed, "he was naturalized in the darkest hour of the war, when the final disruption of the country was confidently prophesied by her enemies. By formally becoming a citizen of the United States he desired to attest his personal confidence in the stability of her constitution and the justice of her cause."²¹

Although the subjects of Agassiz's studies had commonly to be killed, he was not a sportsman. "His passion for Natural History never carried him so far as to shoot birds or animals for sport." The

¹⁹ From the report of the meeting of the joint committee on education of the Massachusetts Legislature as printed in the *Boston Weekly Spectator* for February 12, 1871. Among other obvious misprints Agassiz is made to say that his protest was made "twenty-four" years ago, which would be 1847, whereas the first Cincinnati meeting of the American Association for the Advancement of Science was in 1851.

²⁰ His first wife died July 27, 1848, and in the spring of 1850 he married Miss Elizabeth Cabot Cary, of Boston, who became his "guardian angel."

²¹ Mrs. Agassiz, pp. 568, 570.

creatures needed were put to death, as were the mortally wounded soldiers by old Ambroise Paré, "doucement et sans cholère."

An even more impressive exemplification of the apparently paradoxical character of Agassiz was his attitude toward theology. His writings contain abundant evidence of his firm belief in the existence of a Creator, but he would not discuss dogmas and repelled as impertinent the too prevalent American fashion of asking what church a man attends. So while criticized as a bigot by some scientists he was denounced as an infidel by some theologians because he could not reconcile the facts of geology with the literal interpretations of Scripture. In this regard, with Lord John Russell in politics, Agassiz might have said he was "sure he was right because both parties found fault with him." To the "righteous overmuch" who may hesitate to unite in this commemoration of one who seemed to make light of Genesis and to pass over Adam as if he had never existed, is commended reflection upon the following incidents: On the eighth of August, 1873, commenting on the death of an assistant, he said, "My time will come soon, and I am ready." In four short months that time had come.

On the first of May, 1868, to my remark that I could not understand why Providence and the community had allowed him to lack the means for the complete development of his plans, he replied, "I suppose it is all right; had I obtained all I wished it might have gratified my ambition too much."

At the opening of the Penikese School, July 8, 1873, Agassiz said: "I think we have need of help; I ask you for a moment to pray for yourselves." The incident was commented upon as follows by Henry Ward Beecher:²²

It seems to us that this scene of Agassiz and his pupils with heads bowed in silent prayer for the blessing of the God of Nature to be given to that school then opened for the study of nature, is a spectacle for some great artist to spread out worthily upon canvas, and to be kept alive in the memory of mankind. What are coronations, royal pageants, the parade of armies, to a scene like this? It heralds the coming of the new heavens and the new earth—the golden age when nature and man shall be reconciled, and the conquests of truth shall supersede the conquests of brute force.

As an American, as a student and teacher of science, and as a member of Cornell University,²³ I might, like hundreds of others, take some part in this commemoration. But there are special reasons why, when possible, I have complied with requests to speak or write of Agassiz, and why the invitation to give the present address was accepted with joy and with a sense of obligation, notwithstanding its preparation has seriously

²² In the *Christian Union*, July 15, 1873, p. 51. See also "The Prayer of Agassiz," by Whittier.

²³ As delivered the address described what Agassiz did for Cornell University, directly and indirectly; see the *Cornell Era* for June, 1907, pp. 441-446.

interfered with prior plans for purely scientific work. I am one of the few survivors of those who were directly associated with Agassiz as pupils, assistants or colleagues. He inspired me with interest, with admiration, with respect, nay, almost veneration. No shadow ever came between us. Whatever benefits he may have conferred upon others, I have reason to believe that, outside his family circle, there is no one, living or dead, who has such cause for gratitude and affection in return for counsel, for encouragement, for opportunity, and even for material aid in the form of specimens or information.

The following statements are based not only upon my vivid recollections but upon my diaries and upon the letters of Agassiz, all of which have been preserved.

I am unwilling to speak of myself on this occasion, and yet I do not know how else I can do justice to one of the most beautiful sides of his character. His sympathy for all young students of nature was one of the noblest traits of his life. It may truly be said that toward the close of his career there was hardly one such in this country who was not under some obligation to him.²⁴

As of yesterday I recall the first interview, now half a century ago. At the age of fifteen (in the middle of the last century a considerably less mature epoch than at present) some observations of mine upon spiders were brought to the notice of Agassiz by one of his assistants, James E. Mills, and led to an invitation to visit him. In my "Entomological Diary" he is described as a "very pleasant, fine-looking gentleman." Now I should write, "The most fascinating and magnificent of men."²⁵ At once I appreciated the saying current in Cambridge that in winter one needed an overcoat less while passing his house. His commendation of the spider essay led my parents to grant my request to prepare for the profession of naturalist.

That preparation comprised (1) Two more years of Latin and Greek to complete the Harvard entrance requirements in those languages; (2) additions to the collection of insects that formed the nucleus of the collection at Cornell; (3) reading the first two volumes, just issued, of Agassiz's "Contributions to the Natural History of the United States" (Turtles, and Essay on Classification). This was done before breakfast, and such was my conviction of its value that, although the text was largely unintelligible at that stage of my progress, I felt fortified for the ordinary tasks of the day somewhat as is the religious neophyte by his matutinal fasting and prayer. The experience is related as a warning rather than as an example, but it illustrates the influence unconsciously exerted by Agassiz upon those whom he had welcomed to the scientific fold.

That influence was similarly illustrated while attending his lectures

²⁴ Slightly altered from Agassiz's address on Humboldt, p. 44.

²⁵ In a letter dated Charleston, S. C., March 12, 1853 (printed in the *Century Magazine* for December, 1903, p. 188), Thackeray describes Agassiz as a "delightful, *bonhommi*ous person, as frank and unpretending as he is learned and illustrious."

at Cambridge in my first year. No topic was so vital as the general problem of animal life, and no expositor could compare with Agassiz. As an outlet for my enthusiasm each discourse was repeated, to the best of my ability, for the benefit of my companion²⁶ on the daily four-mile walk between Cambridge and our Brookline home. So sure was I that all the statements were correct and all the conclusions sound that any doubts or criticisms upon the part of my acute and unprejudiced friend shocked me as a reprehensible compound of heresy and *lèse majesté*.

From the fall of 1866 until, mainly upon his recommendation, my connection with Cornell University, I was employed in making preparations to illustrate the structure of sharks and rays for his projected volume upon those fishes.²⁷ This work brought me into relations with him, more and more close, instructive and delightful. From my diaries and letters are selected a few incidents exemplifying phases of his nature not generally appreciated.

Speaking of Darwin, whose doctrines he vehemently opposed, he remarked: "Much as we disagree, we are truly friends."

With some earlier assistants there had been a serious disagreement ending in temporary estrangement;²⁸ yet when their names were mentioned before him he made no adverse comment. He once showed me a letter from one of them asking permission to examine certain specimens at the museum. Upon my remarking that the presence of that man might not be very pleasant for him he replied, almost with reproof, "It is true that I have built up this museum, but I am only its trustee, and if the devil himself wished to study here he should be welcome."

His tenderness is shown in the following incident. The artist who was drawing the plates for the volume upon sharks and rays above mentioned was an elderly German who, uncertain of the term of his employment, had left his family in St. Louis. At last, in his loneliness, he sent for one of his children, a lad of ten. Supplied with credentials of various kinds, the boy reached Cambridge and inquired for "Herr Professor." It was after dark and Agassiz sorely needed rest after a long day at the museum. Yet, instead of summoning a servant, he took the child by the hand, walked with him several squares, and delivered him safe to the anxious father.

The summer of 1867 I spent literally at his side in the laboratory adjoining his summer home at Nahant. Together we dissected the sharks and rays that were brought in by the fishermen. To the paraphrase, "No naturalist is a hero to his laboratory assistant," he was

²⁶ James Herbert Morse, Harvard, '63.

²⁷ See his report as director of the Museum of Comparative Zoology for 1867, p. 10.

²⁸ The full merits of the case may never be understood, and this is not the place for its discussion; but in the light of my own experience with him, on the one hand, and with my pupils and assistants, on the other, I incline toward his view of it.

an exception. For me that summer was a scientific idyl. That the pleasures of my memory of it are less than perfect is due to my later realization of how inadequately I appreciated my privileges and opportunities. Three specifications in the general charge of my unworthiness will serve to set his own tact and delicacy in a clearer light.

A fisherman brought a hammer-head shark. Although familiar with pictures of its rather strange form, I had never seen a specimen, and expressed my interest somewhat exuberantly. The man named a certain price, and Agassiz paid it. When he had gone, Agassiz said to me seriously, but with no shade of rebuke: "This shark is not so very rare, but your outspoken surprise led the man to ask about twice what it was really worth." After that I would have held my peace in the presence of the "sea-serpent."

Agassiz was paying me one dollar per hour, an arrangement convenient for both, especially in the summer. I wished to learn stenography, and studied that early in the day, going to him about nine o'clock. One hot July morning I found him grieving over the rapid deterioration of some specimens that had been brought in at daybreak. I explained the cause of my delay, and added that, but for the necessity of earning my living, I would gladly work for him all the time and for nothing, in return for what I learned from him. "Ah," he said, "I hoped you felt so, but I was not sure. Now we are like lovers after the important word has been spoken." Not for all the short-hand systems ever devised would I lose the memory of those words and of the look that accompanied them.

In those days (it was forty years ago) it might fairly be said that about the brain, zoologists knew little and cared less. No one of my teachers had made a special study of either its structure or its functions.²⁹ That summer, however, Agassiz studied the brains of sharks and rays, exposing them by "whittling" the cartilaginous skulls with a jack-knife given him by Longfellow (who, by the way, made a visit to the laboratory). He compared the various forms with the only published plate we had (that of Dumeril), and would sit poring over them by the hour. Occasionally he would show them to me, and ask if I would not like to work at them. (Remember that he was paying me out of his own pocket and was entitled to assign all the subjects.) No, I had started upon some other parts of the anatomy, and was indifferent. That is too mild a term; I must have been a compound of a mole and a mule. He sighed and gave it up. That I then made the mistake of my life I did not perceive until years afterward, too late to repair the loss. Now, by way of atonement, I in-

²⁹ In 1844 and 1845 Agassiz published two short papers upon the brains of fishes; in "A Journey in Brazil," p. 244, note, he deplors the loss, in a storm, of a lot of brain preparations in a cask that had been left on deck. In the last but one of the twenty lectures given at Cornell University, he said, "The brain is the organ that determines the rank of animals."

sist that the objective study of the brain should begin in the primary school,³⁰ and I look forward—however undeservedly—to the period when no other subject need claim my attention. At times, however, I speculate as to what part of the nether world is paved with ignored advice and neglected opportunities.

His helpful attitude toward prospective teachers was exhibited in the following incidents. After my appointment to Cornell University in October, 1867, he arranged for me to give at the Museum a course of six "University Lectures," and warned me to prepare for them carefully because he should give me a "raking down." He attended them all (at what interruption of his own work I realize better now) and discussed them and my methods very frankly with me.

A year later, while at Ithaca, he attended several of my lectures upon physiology, although they broke up his forenoons and the subject did not interest him particularly. After one he expressed his approval of its simplicity and the absence of hifalutin,³¹ and advised me to counteract the effect of lecturing by investigation. Another lecture dealt with the structure and functions of the heart, for the illustration of which we had excellent charts and models although not, at that time, any actual specimens. I believed that I had done very well, and accompanied him down the hill toward his hotel in the hope that he would say something complimentary. All he said was, "After lecturing upon a subject I have found it a good plan to go to work and study it some more." Then he began to talk of the glacial scratches upon a big rock that we passed. The justice of his criticism was equal to the delicacy of its conveyance.

The work done by me here in 1871-3 upon the brains and embryos of domesticated animals has been referred to already as one of the indirect benefits conferred by Agassiz upon this university. His satisfaction with the results evidently led him to make a most honorable overture and invitation. On the seventeenth of November, 1872, he wrote a letter beginning: "I wish I could have you permanently in Cambridge as professor in connection with the Museum and the University. The first thing to know is whether such a plan would suit you and under what conditions you could accept a proposition, etc." The matter was discussed at more length in letters dated December 7, 1872, and September 10, 1873. It has never been mentioned before by me, but there seems to be no longer reason for reticence.

The second letter contained also the invitation to be one of the instructors at the summer school already mentioned on p. 12. He

³⁰ Upon this point see my papers in *Science*, December 17, 1897, p. 903, and May 26, 1905, p. 814.

³¹ This, the only approach to slang that I recall from his lips, doubtless referred to my introduction of a somewhat far-fetched quotation from Shakespeare in an address before the Harvard Natural History Society, reproduced in the *American Naturalist*, Vol. I., p. 421; it was my first and last transgression of the kind.

wrote: "Among my plans is a course of practical instruction in Natural History at the seashore, during the summer months, chiefly with the view of preparing teachers to introduce Natural History into our schools. . . ."

In the two cases just mentioned it may be said that the advantage was mutual although mine much more than his. But in the following instance his words and deeds can bear no other interpretation than disinterested willingness to aid another at his own inconvenience.

In preparing for a course of lectures before the Lowell Institute I wished to dissect the limbs of certain rare animals which we could neither collect nor afford to buy. On making my wants known to him he promptly took a knife, went with me to the museum store-rooms, and with his own hands cut an arm and a leg from each of several precious specimens. In thanking him I said I had reason to believe that the invitation to give the course was due largely to his having taken the trouble to commend me to the curator; and that I wished he would let me make return by doing some work for him without compensation. He replied, emphatically, "I could not think of it; it is my business to help young men."

In Agassiz were combined five qualities, not uncommon singly or even by twos and threes, but rarely so completely united or so highly developed in one personality, *viz.*, attractiveness, eloquence, strength, energy and helpfulness. As distinguished from Napoleon, from Bismarck, from Goethe, and even from Washington and Abraham Lincoln, Agassiz was at once fascinating, persuasive, powerful, active and uplifting. Under my personal observation have come but two others comparable with him in this most potent combination of great qualities, *viz.*, Henry Ward Beecher and Phillips Brooks. They were preachers; so was he. They based their ministrations upon what they regarded as the Word of God; he drew his texts from what, with equal faith, he held to be the works of a Divine Creator. They were also alike in this; never was voice or hand raised otherwise than for the betterment of mankind.

On returning from Penikese in the fall of 1873 I went to the museum to arrange some specimens, when he came in and reproached me for not letting him know I was there. I explained that I knew he was tired and ill and that I would not take his time. He replied, "Doctor, you are always kind," and those last words have been treasured as a benediction. This coming fifth of September it will be thirty-four years since I beheld my teacher, friend and benefactor in the flesh, but in my mind's eye his image will never fade. Take him for all in all I ne'er shall look upon his like again. Would that it might be justly said of all great men, as I now say of Agassiz: The sun shone brighter at his birth, and shadowed when he died.

NOTES ON THE DEVELOPMENT OF TELEPHONE SERVICE

BY FRED DELAND

PITTSBURGH, PA.

X. EARLY AERIAL TELEPHONE CABLES

PROBABLY John I. Sabin was the first telephone man to use an aerial cable. In connecting his line in San Francisco in 1879, he did not run his circuits into a cupola, as was then the fashion, but employed several lengths of a special cable made by Eugene F. Phillips, of Providence. This cable was composed of forty No. 20 soft drawn copper wires, double braided with cotton, then double wrapped in reverse order with rubber paper, the whole being wound with a cotton or jute covering. It cost 20 cents a foot at the factory. It was suspended by using long canvas slings about two feet apart and attached to two heavy iron wires.

In referring to the growth in overhead circuits, Mr. Phillips stated that:

The natural increase in the number of aerial wires created a demand for better insulation and grouping in cables. Hundreds of miles of No. 12 iron wire were braided and dipped in suitable compound for this use. The annoyance from induction soon made a call for anti-induction cable. This want was supplied by a tin-foil cable so called, in which each conductor, after being insulated, was enclosed in a strip of this tin-foil. Cotton-covered wires to the extent of 50 or 100 were cabled together, and after being saturated with paraffine were placed in a lead pipe. This style of aerial cable, although quite satisfactory, has to a great extent been replaced by the paper-insulation underground cable of the present day.

Aerial cables were in use in New York City late in 1879, and before the close of 1880 a total of over 75,000 feet was in use in the city and on the Brooklyn Bridge, principally of ten-conductor capacity. In September, 1880, C. E. Chinnock told the delegates to the first telephone convention:

We have over the East River bridge at the present time, four cables, 3,800 feet long, each cable with seven conductors. These cables have taken the place of cables that were previously there with the ordinary kerite and gutta-percha insulation. In using the cables and talking on one wire, you could hear whatever was said on another wire, and by wrapping each conductor with lead and grounding at intervals, all of the escape and all induction were completely eliminated. These cables have been in use, two of them for six months, and one for nine months, and are now working perfectly.

In May, 1880, W. D. Sargent used a lead-covered aerial cable to connect two exchanges in Philadelphia. This cable was made by David Brooks, Jr., son of the inventor of the Brooks cable. It was

composed of 42 twisted pairs of No. 18 cotton-covered wires, which were wrapped together and drawn into a lead pipe one inch in diameter. Then a mixture of melted paraffine and rosin was poured into the pipe, the whole forming a solid mass on cooling. This cable was about 600 feet in length and was suspended from three heavy iron wires by loops made of No. 14 iron wire.

At one of the telephone conventions C. N. Fay stated that the use of cables for telephone purposes in Chicago began in 1879, when a 50-wire Brooks oil-pipe cable, 925 feet long, was placed in the Washington Street tunnel under the bed of the Chicago River. The conductors were made of No. 20 copper wire, insulated with cotton, and drawn through an iron gas-pipe previously polished smooth on the inside. The ends of the pipe were elevated, and upon each end was placed a reservoir capable of holding three or four gallons of paraffine oil. After the pipe was put in place, the cable was drawn through. Paraffine oil was then poured into the reservoirs until the pipe was filled from end to end and both reservoirs were full, when the caps were screwed on and the whole made tight. There was a loss of oil from evaporation and leakage through the pipe, requiring a refilling about once in six months. In 1880, a 75-pair cable of similar construction, 450 feet long, was placed in the LaSalle Street tunnel under the Chicago River; another one being placed in the spring of 1881. In 1884, all the oil-pipe cables were in good and satisfactory working condition. . . . The first aerial cable was put up in Chicago in September, 1882, and was a 50-pair Patterson cable 1,350 feet long.

Six Brooks oil-pipe cables were in use early in 1880 in Milwaukee. Each cable was about five hundred feet in length and composed of fifty single conductors, and all were considered "very satisfactory."

It is of historical interest to note that in April, 1843, S. F. B. Morse detailed to the Secretary of the Treasury the specifications under which forty miles of a four-conductor lead-covered cable would be made. Each wire was to be

once covered with cotton thread, to receive two coatings of shellac varnish; then wound with a different colored twine to designate, in case of necessity, any particular wire in any part of the course. The four lengths are then laid side by side and bound together in a single cord by another winding of cotton twine. The conductors thus prepared are ready to be introduced into the lead pipe.

XI. FORCING TELEPHONE WIRES UNDERGROUND

When the underground question first came up, the leading telephone companies made it clear to the authorities of the respective municipalities, that any hesitancy in removing overhead wires and placing them underground was not due to an unwillingness to make the additional and very large investment necessary, but to contending with obstacles that then appeared insurmountable. There was no practical underground system suitable for telephone distribution in American cities. Several experimental systems were being promoted, but all appeared to possess little practical value. One promoter laid a half-mile of his pipe underground and then invited a large number of telephone, tele-

graph and electric-light men to thoroughly inspect the condition of pipes and wires. Following this inspection came a banquet of nine courses, at which eight different wines were served to more than a hundred guests. Referring to proposed drastic legislative action to force the wires underground, David Brooks wrote on March 13, 1882:

I have every reason to believe that the great quantity of poles and wires that are now so objectionable in our streets may be dispensed with in the future, and while the company is so earnestly engaged in testing this problem of underground wires, I can see no good result to be obtained by the passage of these bills. It will be to their interest to make an underground system whenever it is practicable.

The attitude of the parent Bell company on the underground question is shown in President Forbes' annual report dated March 18, 1882, in which he states that

our experiments in underground cables, while not as successful as we had hoped, have given sufficient promise of satisfactory results to warrant us in undertaking at considerable expense to test the different methods. With this object, we have asked permission to put down cables in Boston, and, as soon as the needed consent is obtained, we propose to make careful and thorough practical tests of the best systems offered. . . . The cost of replacing an extensive overhead system in a large city is so serious that it can not be hastily decided upon; yet, if the wires can be laid underground and made to work rightly, at a cost which will not be prohibitory, it is hoped that the service will be better than now, and the cost of operating less than by overhead wires.

The first Morse telegraph patent of June 20, 1840, refers to the wires being laid underground, and a portion of his first telegraph line was buried, but proved inoperative, while on a section built with the aid of cattle-horns used to support the line on and insulate it from a stone viaduct, good service was secured. But the first American patent for underground lines was issued in 1869, and it was the only one issued until 1873, when two more were issued. A total of twenty-one patents were issued prior to 1880, when, in that year, seventeen were issued, and twenty-eight in 1881. Aerial as well as underground conduits, evidently based on the old Graves method of 1858, or the Carter of 1875, were also suggested as a remedy for the multiplicity of overhead wires, and elaborate systems supported upon iron posts or columns erected either on one side of a street or overarching the roadway and supporting the wires in the center were made, upon paper, to appear very attractive, and earnestly advocated as a practical public improvement. In fact, the opinion was expressed at the third telephone convention held at Saratoga Springs, that

with a light and ornamental aerial cable support the requirements of the public could be satisfied and the introduction of subterranean wires obviated entirely or confined wholly to important trunk routes. . . . The Scott elevated wire-way system consists of cupolas located upon housetops, separated at any convenient distance and connected by a suitable tube, through which wires to the number of two or three hundred are drawn and properly connected at the cupolas. The

tube is preferably made of rubber and braided fabric upon a spiral foundation of wire, by which the tube retains its circular form. The tube is suspended from a supporting wire of sufficient strength to stand the strain of severe wind and the weight of accumulated ice and snow. The wires, which may be either well insulated or even the ordinary braided or double-wound wire, can be drawn in singly or in groups and connections made at the cupolas. The tube, being impervious to moisture, the channel inside will remain perfectly dry. Since the last report of the committee, it has been introduced on a limited scale in the city of Boston and it will soon be extended.

While no underground system satisfactory to telephone men was available in 1880-3, a few wires had been laid underground and some experience of an expensive character gained. For instance, the Western Union carried out some costly experiments with underground wires in New York City during the four years, 1876-80. In 1876, two 4-inch iron pipes were laid from the main office to Pier 18, a distance of one third of a mile. In each pipe

was placed a cable of sixty conductors, the wires insulated with gutta-percha, and wound separately with a layer of tarred tape, the whole covered with a double layer of heavy tape tarred and run through sand to prevent sticking to the pipes.

These cables were connected to the submarine cables running to Jersey City. In 1876, a 12-conductor cable about 2,200 feet in length was laid between the main office, 195 Broadway, and the branch office on Broad Street. Owing to the proximity of steam pipes and the destructive effect of gas on the insulation, these cables were short-lived. In 1880, a new 28-conductor cable was laid between the same offices. Before the end of 1882, eleven of the conductors were useless. In May, 1882, sixty circuits were laid between 195 Broadway and 134 Pearl Street, only to be abandoned within a year, every circuit having failed within seven months. On November 28, 1888, it was stated that the result of the Western Union

experiments during the past twelve years proves that there is no form of underground cable and conduit which can be depended upon to give more than four or five years' service under the most favorable circumstances.

In 1878, John P. Barrett, superintendent of the city telegraph system, placed the fire-alarm and police signal wires underground for a distance of 840 feet on a handsome residence street in Chicago. Two-inch iron pipe, the interior of which was heavily coated with tar, was laid underground and into this pipe two kerite insulated wires were drawn. Ten years later it was stated that these wires had given no trouble and were in 'practically as good a condition to-day as when so placed.'

Submarine telegraph cables were in use thirty years before the first telephone exchange was opened. Referring to the first one used in this country, Henry A. Reed said:

This cable was of No. 9 iron wire, insulated to the thickness of half an inch and was made in 1847 by Stephen Armstrong in Brooklyn, N. Y. It was laid

across the North River at about Fort Lee. It only worked a few days when it was dragged out of place by a ship's anchor. The first iron-armored cable was made by S. C. Bishop in 1852, and was used across the North River, above Cold Spring. This cable was of No. 14 copper wire with an insulation the size of No. 0, protected by jute and armored with iron wire about No. 8.

Submarine telephone cables were used in 1879 by several companies in crossing rivers and bays, notably in Chicago and Milwaukee, and Patterson telephone cables were placed in the Washington Street tunnel crossing under the Chicago River, in 1879, as previously stated. But probably the first telephone cables that formed a part of a regular underground system were laid in Pittsburg in 1881, by Henry Metzger. Three lead-covered cables were laid on Fifth Avenue between the exchange and a distributing pole, about a thousand feet distant. The cables were composed of 50 single conductors of No. 26 copper wire, and were placed in a wooden box, 6 x 8 inches, made of one-inch plank, that was then filled with asphalt and laid inside the curb below the frost line. No manholes were used, but connecting wires were spliced with a T-joint. In June, 1882, Mr. Metzger laid eight more Patterson cables underground, the longest being 2,200 feet in length, composed of No. 18 B. & S. single copper wires. These cables gave good service for a number of years. That same year, 1882, the New England Telephone and Telegraph Company laid two Patterson 50-pair cables in Boston, for metallic circuit service. The lead-covered cables were drawn in iron pipes laid in cement. One cable was 1,200 feet and the other 1,485 feet in length; both were composed of No. 22 wire, cotton covered. One was laid in Pearl Street in October, the other in Franklin Street in November, 1882.

On May 20, 1882, Professor Chas. R. Cross, in considering the various electrical problems involved in the introduction of underground telephone cables wrote:

In the first place it should be remembered that the number of wires in foreign cities is probably not more than one fifth as great as in American cities of equal size. Thus in Bruges, Belgium, a city of 50,000 inhabitants, there is but one telegraph office, that at the railway station; in Ghent, with 120,000 inhabitants, there is but one telegraph office; in Antwerp, with its enormous commerce, there are but two, one being at the railway station; and in Brussels proper, only one office except at the railroad stations.

In London and Paris almost all messages are sent from the outlying offices to the central telegraph office by means of pneumatic tubes, and the telegraphic despatches sent from there. From these facts it will be seen that the absolute number of underground wires in foreign cities is much less than is popularly supposed. Contrast in this respect Boston and suburbs, with 377,000 inhabitants and forty-nine telegraph offices, and Brussels and suburbs with 315,000 inhabitants, and eight or at most ten offices.

In April, 1882, thirty-eight sections of a lead-encased telephone cable were laid underground between the two tracks of the Boston & Providence Railroad extending from the depot in Attleboro to West

Mansfield, a distance of about five miles. The cable was made by Eugene F. Phillips in sections of five hundred and thirty feet, and connected by means of junction boxes, and he gave the readers of the *Electrical World* (March 4, 1899), an interesting account of the manner in which the cable was laid. In part, Mr. Phillips said:

In 1882 the American Bell Telephone Company, wishing to make some practical experiments on telephonic transmission with underground wires, ordered of us a cable to be 5 miles in length, containing twenty-one wires of No. 20 B. & S. gauge, a majority of which were to be insulated with rubber and the balance braided with cotton and paraffined; part of the conductors to be covered with tinfoil, and part twisted in pairs for metallic circuit; also a single conductor of No. 13 B. & S. gauge braided and paraffined. We believe this was the first underground experiment made for the American Bell Telephone Company, and the laying of this cable was a red letter day for us. The American Bell sent an engine and one open-end freight box car, which carried the 5 miles of cable we had already made to Attleboro, as well as fifty men for a working force. In laying this cable a trench was started by means of pick and shovel, but it was soon found the hard roadbed was by no means easy digging. A plow was borrowed of one of the farmers and attached to the outrigger from the truck of a car, pulled by an engine. As we were unable to hire oxen or horses to plow with, this idea was suggested by W. H. Sawyer, and it made a fine specimen of plowing, the like of which was probably never before witnessed. When the trench was completed, two plows had actually been consumed in the process. The cable was placed at the end of the car and paid out into the trench as the car moved along, and close behind the plow in the furrow. The filling of the trench was also another great conundrum; the gang started with shovels and hoes to do this, but it at once became evident that it would be a week's work with the force at command. Again Sawyer's inventive genius came to the rescue. At his suggestion a joist was procured, and one end lashed to the cowcatcher of the engine, the other end extending out over the trench on the side where the dirt had been thrown. The engine was started, and the entire length of the trench and cable was soon covered, much to the pleasure and satisfaction of those looking on as well as those responsible for the filling.

Notwithstanding that prior to 1890 no underground system proved satisfactory from a telephone engineer's point of view, yet the rapidity with which the telephone companies responded to the public demand that the wires be placed underground is apparent from the fact that while the underground movement started in 1881, at the close of 1884 there were 1,225 miles of wire underground, and ten years after the first telephone cables were placed underground, over 70,000 miles of wires were in subterranean ducts. To-day over one half of the total mileage of telephone circuits in use by Bell subscribers is underground, that is, nearly three million miles of copper wire are buried in the earth.

XII. THE EFFECT OF ELECTRIC STREET LIGHTING ON TELEPHONE SERVICE

While an inability to dispose of the securities of the local companies retarded the growth in subscribers in many exchanges, in 1883-5, other causes were also hindering the expansion of the telephone in-

dustry. One cause was the rapid introduction of electric-light circuits, so poorly insulated as to sadly interfere with good telephone service and necessitating the rearrangement or reconstruction of many telephone circuits. As already stated, the first street lighting occurred in Cleveland in April, 1879, with Brush arc lamps. In San Francisco the Western Electric Light Company was organized by G. S. Ladd, and on February 6, 1879, was supplying current for private service according to *The Bulletin*, which said:

Yesterday the Western Electric Light Company made connection with the Gold & Stock Telegraph Company, and now all the electricity used in running their stock indicators throughout the city is supplied from the Gramme machines, thus doing away with five hundred cups, which heretofore composed their battery.

It is stated that arc lamps were in service in San Francisco in October, 1879, the rate then charged being \$10 a week when burning from dark till midnight.

It was fortunate for the continued broadening of the telephone industry that it got a strong foothold before the parent electric-light companies began to devote their energies to belittling each others machinery and motives, or to determine whether it was wiser "to advocate the use of sixteen small single light arc machines, with their costly system of conductors, or one sixteen-light arc dynamo," instead of perfecting the insulation on pole line circuits, even if they did not increase the efficiency of their apparatus. Otherwise the electric transmission of speech might have had a different growth recorded. For the character of the crude and cheap telephone construction prevalent in 1878-80 would not have been tolerated by the public in 1882-3, by reason of the number of violent deaths resulting from accidental contact with live wires, deplorable accidents that started a rabid agitation in favor of placing all wires underground. No underground system suitable for telephone circuits was then in existence, and had one been available, the heavy initial cost of installation would probably have deterred many investors from entering the telephone field under such unpromising conditions.

In New York state alone more than a hundred electric-lighting companies, having an average authorized capitalization exceeding a million dollars each, were incorporated before the close of 1883. And as the electric lighting industry was raw and untried, as suitable or even satisfactory line insulation had yet to be devised and tested, and as competition among electric-light companies in many sections was destructively fierce, it is needless to say that the unsafe construction of the average competing electric-light company was such a menace to the satisfactory continuity of telephone service that telephone managers were compelled to forego making verbal or written indignant protests, and to devote every moment of time to devising methods and means for protecting their equipment from the

destructive effects of stray currents. Even then, imperfect protection resulted in the complete or partial destruction of several telephone exchanges. Following the destruction of one exchange, Mr. A. S. Hibbard suggested that in view of the delay in getting large switchboards in emergencies, it would be a wise thing in the way of insurance, if a number of telephone companies would jointly buy a complete central office equipment, to be built and held in convenient storage, with the understanding that it should go to the first company whose exchange was burned, and that that company would pay its cost price or replace it with new equipment.

Referring to the introduction of electric-light circuits, Mr. W. J. Denver told the members of the Boston Electric Club:

I remember the first time the arc lights were exhibited in my native city, and what a tumult was caused at the telephone office. An electric light circuit was strung, using the ground for a return and four or five lights were placed upon it. Immediately on the starting of the dynamo, up went the lights and down went the switchboard drops, and the confusion of tongues consequent upon the building of the tower of Babel was as the stillness of death compared to the racket on the telephone wires. . . . The remedy was evident; double the light circuit, which was done the next day.

When the electric-light industry started, the electric lighting fraternity turned to the telegraphers for assistance and advice, just as the telephone men did. But the electric-light men also had the advantage of the experience gained by telephone men in building local circuits. It is written that the first electric-light switching devices were derived from the telegraph switch, only enlarged to accommodate the greater volume of current. The strap key, the telegraph key and the switchboard plug were all utilized in central-station electric lighting, and the arc that formed between the terminals following the withdrawal of the plugs was usually blown out with the breath, or whipped out with a cloth, or extinguished with a handful of sand.

In other words, the same degree of crudeness was just as strongly in evidence in primitive electric-light plants as in the pioneer telephone exchanges. And, as one writer stated it in 1882, there are electric-light charlatans as well as medical quacks, charlatans totally ignorant of the electrical laws, and with no experience in electric lighting.

One point worthy of note is that the telephone engineer soon found that he must not only be able to solve telephone problems, but must also be thoroughly conversant with every phase of electric lighting, and then of electric power and of electric traction that was in any manner likely to have a bearing on or to influence the character of telephone service. Thus, as the editor of *The Electrical World* has so concisely stated:

In the telephonic engineering done by Carty and his colleagues there is no parallel whatsoever to be found in any other branch of electrical engineering.



THE GREAT JAPANESE VOLCANO ASO

BY ROBERT ANDERSON
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A SO-SAN, or Mount Aso, is a living volcano in the heart of the island Kiushiu, Japan, whose peaks rise to a height of several thousand feet out of a gigantic bowl. This bowl, which is many miles across, is an ancient crater surpassing in size all other known craters nearer than the moon. Some 5,000 people, grouped in half a hundred villages on the old floor, are living to-day, tilling the volcanic soil and trading in this vast crater, round about the base of the new and ever-active cone that has risen in it.

Kiushiu is the most southern of the four main islands in the Japanese archipelago. It is about 17,000 square miles in extent and is therefore larger than Vancouver Island, or almost equal in area to Massachusetts and New Hampshire combined. It is built up of very ancient rocks, both sedimentary and igneous, belonging to the paleozoic and mesozoic eras, as well as of younger rocks, and upon these as a foundation has been erected in more recent times, partly during the age of man, a superstructure of volcanic materials which now covers many thousand square miles, or about one half the area of the island. It contains twenty volcanoes, counting two that are just off the coast to the south, of which eight are now active. Among them Aso-san is on far the largest scale, though now it is in a decadent stage and is surpassed in activity by two or more of the others. Japan through all past ages has been a land of extraordinary geological activity, possessed of a vital energy which, continuing in force up to modern times, has been emphasized by the changes in level of its coasts and heralded by its ever-vigorous volcanoes. It is far from being a land solely of volcanoes and volcanic formations, as is sometimes thought, for these assume insignificance when compared with the wide areas and great thicknesses of strata that are representative of almost every stage of the geological column. But that it is a country of great volcanoes there can be no doubt. They have flourished ever since the beginning of its geological history and to-day there are 164 independent volcanic cones, or colonies of related cones, scattered through the Japanese islands, including the Kuriles and the Liu Kiu chains. Of this number 54 are now actively grumbling and nursing their wrath and occasionally losing all control. Fuji-san and Aso-san are the kings, although others surpass them in destructive activity. The first is famed for the height and regularity of its cone as one among the preeminently symmetrical and beautiful volcanoes of the

world. The other is almost unknown except among the Japanese, although its immense crater is the largest of all that have yet been found on this globe.

The center of Kiushiu is about 600 miles distant from Yokohama and Tokio by the ordinary routes of travel, and by far the best way to reach Aso-san is from Nagasaki, whence one of two routes may be followed—either far around from the peninsula on which Nagasaki is situated, a distance of 150 miles by railroad to Kumamoto, a city on the west coast of Kiushiu, within 25 miles of the volcano, or most of the way by sea, a distance of 75 miles to the same city.

The pilgrim or traveler who mounts to the walls of the castle of Kumamoto and looks eastward over the green and gardened city and over the rich plain bordering the bay of Shimabara, off to the mountains that form the backbone of the island, sees the massive, sacred, god-mountain Aso above a long blue chain. A thrill passes through him as he sees a white cloud streamer waft horizontally across the grey clouds around the summit or, rolling into a ball, float upward like a thistle-down. The white cloud is soon dissipated, but another born from the mountain takes its place as soon, and one knows that here is a volcano, that the god of the mountain is alive. Hundreds of Japanese visit Aso-san every year to pay their homage to the deity that the mountain represents, but only rarely has it been visited by foreigners.¹

During the spring of 1905 the writer and his brother, Malcolm Anderson, and their friend, Kiyoshi Kanai, spent several weeks in the vicinity of Aso-san, staying for many days in one of the villages in the old crater, living in native Japanese fashion and coming in touch with the spirit of the people and the natural history of the region. The way from the west coast to the mountain lies across the Kumamoto plain among little open fields that in the spring are richly colored with deep green wheat and yellow mustard, along a broad avenue eighty feet wide marshaled by stately cryptomeria trees whose handsome bark and foliage remind one of their big cousins—the California redwoods. Beyond the village of Seta at the edge of the lowland, some 13 miles from Kumamoto, one is led up into the mountains by a gentle ascent, the volcano itself being all this time hidden by the intervening slopes. But a backward view reveals the lesser volcano Kimbo-san rising as an independent cone near the sea, and if the day affords one of the clear Japanese skies, which unfortunately are only too rare but which are so beautiful when they come, one sees the

¹ The only mention of Aso and its crater that the writer knows of is in an article by the geologist, John Milne, in *The Popular Science Review*, New Series, Vol. IV., No. 16, October, 1880, and in Murray's 'Handbook for Japan,' by Chamberlain and Mason. The former is an English periodical that has long since ceased publication.

great destructive volcano Unzen-dake springing up to nearly 5,000 feet on the peninsula of Shimabara over across the gulf. One travels to Aso-san as one chooses, either on foot, in a jinrikisha, or in the funny little perambulating dry-goods box known as a *basha*, the Japanese adaptation of the English stagecoach. We preferred to walk, and upon leaving the plain we enjoyed many picturesque miles up the cascading stream Shirakawa. For the first night out from Kumamoto we stopped at a modest little inn, being driven by a pouring rain to take shelter at the hamlet of Tateno, which is perched high up on the side of the canyon that the road follows, at an elevation of about 1,200 feet above the sea. From there on the canyon of the Shirakawa becomes more precipitous in outline, and a short tramp in the early morning along the mountain slopes above it brought us to its brink at a point where it forked and cut squarely across our path. Here, pillared walls formed of roughly columnar lava, through which the stream has cut a grand gorge, drop sheer several hundred feet, and the path descends a zigzag course to their foot, where the two forks toss into one stream over a boulder-strewn bed. Near here a hot saline spring surrounded by the hamlet of Tochinoki, where many bathers come, give the first evidence of the proximity of the volcanic center.

Whichever of the two forking streams one follows, one presently comes up upon a broad plain that is surrounded by heights on every side and that curves around in the form of a great crescent. But, instead of ordinary mountains, the outer convex curve of the crescent is ringed about with an even-topped wall rising on the average about 1,500 feet, while the concave side is bordered by a great rugged mountain mass attaining a height of over 4,000 feet above the plain. The configuration of the region is absolutely unique and one is at a loss to understand its significance until later on, climbing the mountains and gaining expansive views over the whole broad domain of Aso. The truth is this: That a vast oval crater basin occupies the region, but is divided in two by a range of mountains that has risen across its center diametrically. The two portions of the crater thus cut off are the two crescent-shaped plains, whose level bottoms are formed by the old crater floor, whose outer surrounding walls are its rim, while the inner side of each is walled in by the great dividing range. There is but one opening in the ramparts hemming in these basins. It is where the western end of the central range meets the bounding wall. Each of the two halves of the crater is drained by a stream, and these small rivers uniting around the base of the central range at this western end, flow through the common outlet—the grand gateway through which we made our entrance. It is 10 miles across the crater from west to east in the diameter occupied by the dividing mountain ridge, while from wall to wall from south to north it is 14 miles. These figures, it must be stated, are only estimates, but a

number have agreed that they are approximately correct. The oval area occupied by this volcanic bowl is thus over 100 square miles, an area half as large again as the District of Columbia.

The crater of Aso is both for size and structure unique among the craters of the world. The Hawaiian volcanoes, with which Aso shows the most resemblance, are of greater bulk, but their craters, which are usually spoken of as the largest in the world, can not compare in size with that of Aso. The crater of Haleakala, according to Dana, is $7\frac{1}{2}$ by $2\frac{1}{4}$ miles in dimensions, and covers some 16 square miles. It has a greatest depth of 2,500 feet. The Kilauea crater, Dutton gives as $3\frac{1}{2}$ miles long by $2\frac{1}{2}$ miles wide and from 300 to 700 feet deep. The crater of Mauna Loa was measured by Alexander as $3\frac{1}{2}$ by $1\frac{3}{4}$ miles in dimensions, with an area of $3\frac{1}{2}$ square miles. The islands of Santorin south of Greece in the Mediterranean preserve the remains of a crater 18 miles in circumference, and Pantellaria, between Sicily and Africa, one with dimensions of 8 miles by 6. The two Italian crater lakes, Bolsena and Bracciano, are of great size; the one is oval with a long diameter of 9 and a short diameter of $7\frac{1}{2}$ miles, and the other is a circle 6 miles wide. The crater of the volcano Palandökan in Armenia is said by Bonney to be 6 miles in width. Among the volcanoes of the Canary Islands, Scrope mentions the cirque of Teneriffe, which contains a pit 2,000 feet deep and a high peak within it, as being 8 miles long by 6 miles wide, and Bonney the crater on the island of Palma as 9 miles in diameter. A crater on Mauritius is said by Dana to have a longest diameter of 13 miles. Among the great volcanoes of Java, according to Scrope, Papandyang has a crater with measurements of 15 by 6 miles, and Bromo one with diameter of 4 or 5 miles. Crater Lake in Oregon, described by Diller, is one of the most perfect. This nearly round pit is 4 or 5 by 6 miles in dimensions and has a depth of 4,000 feet. But Aso surpasses them all, with a crater equaling 2 or 3 times the combined volumes of the three great Hawaiian craters mentioned.

The journey over the old floor in the midst of such novel surroundings is a unique and pleasing one, but the stupendousness of the scene comes over one more strongly when he looks down upon it later from above. Our little party chose the southern of the two forks and followed it up for mile after mile along its gentle upper course. The distances proved elusive. We looked across the plain to the wall on the other side and it was only a little way, but still as we went the goal seemed no nearer. The ascent from the point of outlet of the streams is at first rather steep. Within about a mile, however, the fork that we followed bursts off the level of the crater floor in a picturesque waterfall. It is called by the Japanese *Aigaeri*, or "trout-return," for beyond this the fish can ascend the stream no farther. The view upward to the mountains surrounding the plain on all sides is mag-

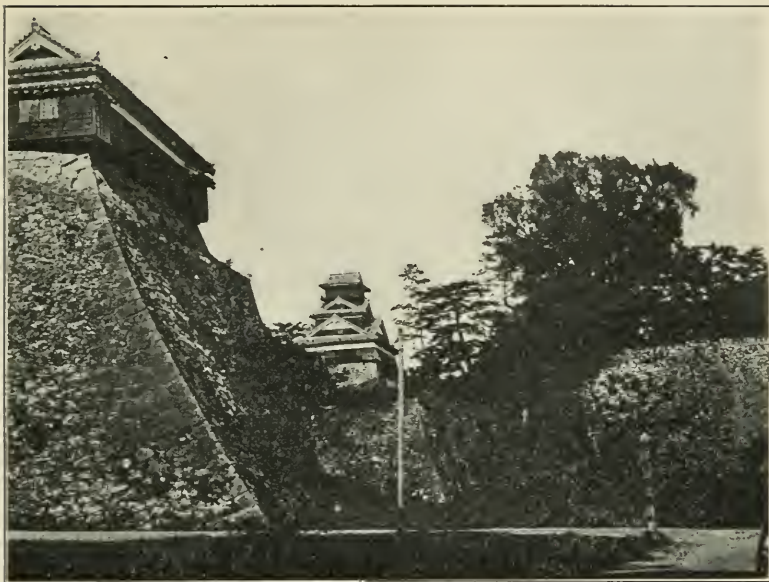


FIG. 1. THE CASTLE AT KUMAMOTO WITH ITS STRONG, UNCEMENTED MASONRY WALLS, BUILT THREE CENTURIES AGO. This style of construction requires a slope to the walls. The author and his brother ran a race to their top and found it quite possible to scale them. The superstructure of the castle was almost destroyed during the Satsuma rebellion in 1877. The view of Aso from the single remaining turret is magnificent.



FIG. 2. HOT SPRINGS AT YUNATANI NEAR THE WESTERN END OF THE ASO RANGE. There is a small geyser here that spouts out boiling water and red mud.



FIG. 3. PANORAMIC VIEW OF THE HIGHEST PORTION OF THE RANGE IN THE CENTER OF the highest peak of Aso-san. On the right is Neko-dake. Photo by Malcolm Anderson.

nificent as one journeys on over the gently rolling surface of the basin floor. To the southwest the ring wall, elsewhere comparatively level-topped, rises up into mountain peaks that are between 2,500 and 3,000 feet higher than the level of the plain. To the north and northeast run the mountains that form the barrier between the two halves of the crater. They make up one massive, rugged ridge whose summit is broken by several dominating peaks. It is this range or ridge that is named Aso-san. On the summit, but at the foot of the highest peaks, at a point about half way from end to end of the Aso ridge, is situated the modern active crater from which rose the cloud that we saw from Kumamoto. A view of the rising steam puffs is again obtained as one comes out into the widening plain above the waterfall. And as one goes farther and finally reaches the central and widest portion the view of the Aso range, which was at first an endwise one and eastward, opens out until one looks to the north upon it broadside. There are three main peaks and many minor ones, the most striking of them being Neko-dake at the farther, eastern end. Its slopes have the graceful curving outlines characteristic of volcanic cones, and its summit is a jagged battlement of monumental lava pinnacles looking somewhat as if they might be the remnants of a shattered crater. Its eastern flank drops down and ends the range by blending with the converging outer walls of the two basins. The next nearest peak is Taka-dake, a higher although less distinctive summit forming the culmination of the range. It is separated from



THE CRATER, looking north across the southern half of the crater. In the center is Taka-dake

Neko-dake by a depression of about 2,500 feet, out of which both mountains rise steeply. The ridge almost loses its continuity in this depression, so that Neko-dake is left as an isolated pyramid with truncated broken summit rising about 2,500 feet out of the highest part of the old crater to an elevation of 4,800 above the level of the sea. Taka-dake on the west side of the gap has an altitude of 5,600 feet above the sea, and is about 4,000 feet above the crater floor around its base, and some 4,500 feet higher than the point where the two streams have their outlet. On the southwest flank of Taka-dake rises the half-dome summit of a third peak, Naka-dake, facing the southern basin with vertical cliffs of black rock that have the appearance of being the cross section of a lava flow. It is from a low point of the range west of this summit that the steam cloud issues from the small modern crater, whose cone is hidden from the southern basin by an outstretched flank of Naka-dake. West of the new crater is another low place which divides the highest portion of Aso from the continuation westward. This gap is about equidistant from the two ends of the range. West of it rise subordinate peaks along the ridge, which gradually sinks lower until it comes to an end near the outlet of the streams. The distance from west to east across the big crater of Aso along the line occupied by the central range is about ten miles. But following the curving course of the crescent basin it is much farther from one side to the other. By the road through the middle of the plain the distance is about eighteen miles. Our little party after

passing through many hamlets and villages between long rows of small houses that line this main thoroughfare, at last, at a distance of twelve or thirteen miles from the stream outlet, reached Takamori which we had chosen as our goal. This is a prosperous small town with several hundred inhabitants, the chief center for the rich agricultural district hemmed within the volcanic heights of this southern half of the old crater.

This whole district is one wide expanse of cultivated fields, a mosaic of little patches differently planted, unfenced and unbounded, stretching freely down the plain in endless kaleidoscopic variety. In the spring-



FIG. 4. LOOKING SOUTHWEST ACROSS THE FLOOR OF THE SOUTHERN HALF OF THE ASO CRATER AT A MUCH WORN PORTION OF THE SURROUNDING WALL. The town of Takamori shows as a spot of white in the distance on the left. Photo by Malcolm Anderson.

time wheat and mustard, growing tall and vigorously, are the dominating crops, and the rich green of the grain mingled with the brilliant yellow of the mustard blossoms spreads a gay succession of tints over the wide plain. Here and there a tree, or a cluster or line of trees, for the most part dark pines or phantom bamboo groves, give a picturesque irregularity to the vast chess-board, standing like players on the light squares or the dark. The villages and groups of farm-homesteads with their conically roofed thatches appear as small as ant-hill colonies when viewed from above from one of the innumerable points of vantage round about, so small are they as compared with the breadth and depth and largeness of the scene of which they are a part.

On a day in April that dawned cloudless and with a frosty chill the writer set out to reach the summit of Neko-dake, the ragged-topped mountain at the eastern end of the Aso chain. As I went among the little fields and along the hedgerows in the early morning, always choosing among many paths one that seemed to lead me eastward, for beyond Takamori no well-beaten road continues farther up the plain, I met several people setting out also for the day. Each one of them looked with wonder at me, a stranger, staring with curiosity but bowing courteously in reply to a morning's greeting. One was a man with his faded bluish-grey kimono tucked up above his knees, leaving displayed a considerable expanse of underwear, his calves swaddled in blue-canvas walking gaiters above the straw sandals on his feet, and his shoulders wrapped in a bright red blanket—a man with the worn brown countenance of a country traveler shaded by a sun-darkened straw hat. He was a type of wayfarer often seen in the out-of-the-way portions of Japan, who, touched by an expanding arc of the great wave of westernization, has adopted a ludicrous cross between the native and foreign dress, a cross that possesses all the characteristics of degeneracy from both of the parent stocks. The next man that passed carried on his shoulder a short wooden steel-bound mattock or hoe, such as the peasants use in cultivating the fields, and another led a bull stout of neck and sullen of countenance laden with a rough plow and other tools for the day's work. These men were coming from their homes out to the particular little patches belonging to them somewhere in the plain. It is customary for the peasants to group their houses in small colonies and sometimes they go long distances to their work. Still another man, who came along the path empty-handed and empty-faced and out of work, was evidently quite resigned to the enforced leisure promising for that day. As I went farther and the day grew the fields became peopled here and there with men and women in small groups heartily beginning their task of digging and planting and nursing the ground. This is their daily occupation and so they live on peacefully, paying no heed to the filmy cloud floating over the crest of the Aso ridge, which now disperses before the spring sun only to return, in one form or another as a misty veil over the mountain top, a dark smoke, or a silvery cumulus cloud standing bright on the blue sky. There is no thought of the living force of the volcano.

The crater floor slopes upward from the outlet toward the east, and Takamori is several hundred feet higher than the level of the floor near the break in the walls where the streams flow out. It rises still more beyond Takamori and breaks from a fairly even plain into undulating hillocks which occupy the angle where the outer wall curving in converges with the Aso range. In this angle I reached the base of Neko-dake and the foot of the wall at the same time. The ascent was up a grass-grown ridge having an even slope of thirty degrees, but becoming

narrow and ragged as it approached the rocky mountain top. At an elevation of 4,750 feet by my barometer, just under the brow of the summit, I caught a glimpse on approaching of what I took to be a lonely wild cherry tree in blossom far up here alone. It proved to be a group of bushes with their bare limbs and twigs bearing little balls of snow, remnants of the winter.

From the mountain top a magnificent view opened and led me for the first time to a comprehension of the structure of the region. I had come from a deep basin on the south of the Aso range and here suddenly was spread out on the north its almost exact counterpart. At about 3,000 feet below the peak on which I stood lay this other far-reaching plain which seemed to be the continuation of the southern one, while round its outer edge it was enclosed by a similar curving wall. The grandeur of the scale upon which all the lines in the scene were drawn made the outlook a most impressive one, and with the view came a sense of the magnitude of the forces that had been at work in molding the large details of such a landscape. The sight was such that it carried with it at once the appreciation of these two huge bowls as parts of a great crater, divided by a high, massive mountain partition.

This crater is almost circular in appearance. Its rim forms a smooth sweeping curve around the whole circumference, broken only at the cleft on the west where the streams pass out, and on the east where it is joined by the slope of Neko-dake. The summit of this outer wall is remarkably even and its inner side precipitous. Although it presents rocky precipices at points on its face, its general slope is by no means perpendicular, but, being steeper as a rule than ordinary mountain slopes, it has a strikingly abrupt appearance. This is especially true in the case of the northern basin, where the wall facing the south is less gashed by lines of erosion, is more sheer, and has a more perfectly preserved even summit than the wall of the southern bowl. The latter wall is furrowed by gulches that have eaten back to the summit in places and notched the sky-line of the rim. Between these gulches sharp ridges run out into the plain, some of them looking more like lava flows descending from the wall than like remnants left by erosion. Such ridges run out into the northern basin as well, and little island-like hills rise in isolated positions from the crater floor. This half, though a close counterpart of the other, is more nearly round and its walls preserve a more even height. The slope up from the floor in both basins is gentle at first at the foot of the walls and then becomes steep. The walls are formed of roughly bedded lava flows interstratified and intermingled with mixtures of vesicular lava, scoria, pumice and volcanic sand. The harder lava layers project with vertical rocky faces, while between them softer zones have weathered away into débris slopes and produced a rough terraced effect, somewhat similar to that in the sides of the Grand Canyon of the Colorado. The height of the

walls above the level of the plain is on the average about 1,500 feet. It decreases toward the western side owing to the gradual rise of the floor in that direction, but increases at some points, as on the southwest and west sides, where mountains break the continuity of the horizon line.

From the brink of the wall around the whole circumference of the big crater, a wide plateau slopes gently away at an angle of only some five to eight degrees. One is apt to think of a crater as a pit on the apex of a sharp conical mountain. The crater of Aso has a cone, but its slopes are so moderate that one realizes only from a point of comprehensive outlook that this vast open bowl lies on the summit of a huge mound, which forms an upland of low relief in the center of Kiushiu.

The outward-sloping surface of this mound, as seen from above, is like a plateau, but it is without a single level place. No surface could be more wrinkled and still preserve the appearance of an inclined plane. It is completely made up of knolls and ridges and knobs, which continue off for many miles to the base of high encircling mountains. From the summit of Neko-dake these distant mountains are seen to surround this upland, much as the walls of the big crater surround its floor. The hillocks of the upland are overgrown in the early spring with long dry grass, but the cultivated bottoms between shine like emeralds, the green of the wheat being deepened here and there by the background of black soil upon which it grows.

From the peaks of the Aso range that divide the two well-populated plains long flowing ridges with concave slopes reach down into the floor. Between them are steep gorges. These ridges are not dwelt upon nor cultivated, probably on account of the lack of water, but like the hills of the outer plateau are grown over with rank grass. They contrast strongly with the richly tinted sweep of the crater bottoms. Considerable patches of the northern plain are sometimes flooded, and there is a legend that the big bowl of Aso was once occupied by a lake until a god kicked the hole in the wall to let the water out and leave the ground for cultivation. One can not but admire the conception of the ease and despatch with which this early piece of reclamation work was carried out.

Nearly all that has been described, and more, can be seen from the top of Neko-dake; so much, in fact, that two or three hours spent on the summit was all too short a time. The descent was quick down the steep slope, but the evening homeward jaunt to Takamori was one of many miles. The way led along a muddy black path; at first among bare fields, where peasant women had been at work all day gathering up corn stalks, loading them on oxen, and sending them home to be chopped up to feed the animals; and then among the endless paddy-fields of wheat and mustard. Finally 'home,' when reached, consisted



FIG. 5. THE MODERN MUD-CONE OF ASO-SAN WITH VAPORS ISSUING FROM THE NEW CRATER. In the foreground is a temple to the God Aso.

of a floor, a few bowls of rice, and a bath through which a dozen men had been before.

On another day the three of us set out for the modern crater. A walk of a few miles brought us to the village of Yoshida about opposite the central portion of the Aso range, whence a feasible way seemed to offer up to the low place in the range already noted. It led first over the end of a number of low ridges that radiate into the plain from the central mountains and then up an easy grassy slope to the top. Here we had expected a divide that would enable us to look over into the northern basin, but instead we found an expanse of almost level mound-strewn country mostly enclosed by the higher portions of the summit

and so wide that it intercepted all view. The mounds covering this upland were seemingly formed of soft volcanic débris and presented a straggling appearance. This summit country sloped upward on the east within less than a mile into a low cone some few hundred feet high, from which the steam clouds poured forth. Behind it on the southeast rose the forbidding-looking crags of Nakadake and on the east the flanks of Taka-dake to a much greater altitude.

At the foot of the cone on the desert-looking slope stood several huts and two small temples, one Buddhist and the other Shinto, built in honor of the god of Aso for the use of those who climb the mountain to worship. It is one of the beautiful features of the Japanese religion as practised by a great many of the people that it draws them out of doors and brings them in touch with nature. Almost every mountain is held in reverence, and many days during the course of the year are spent by the devout in excursions in the country or up into the mountains to pray on the high places.

It is a gentle ascent of only 200 or 300 feet from the rest house and the temples to the summit of the cone, first over a lava stream that looks as if it might have flowed but a little while before, then over a talus of lava, pumice and cinders, and finally over slippery, grey volcanic mud. At the top is the crater, a black, ragged, awful pit, roaring and steaming constantly. As one stands on the brink one looks down walls of roughly-stratified mud to a depth of 300 or 400 feet, where two round vents are continually rolling out masses of steam

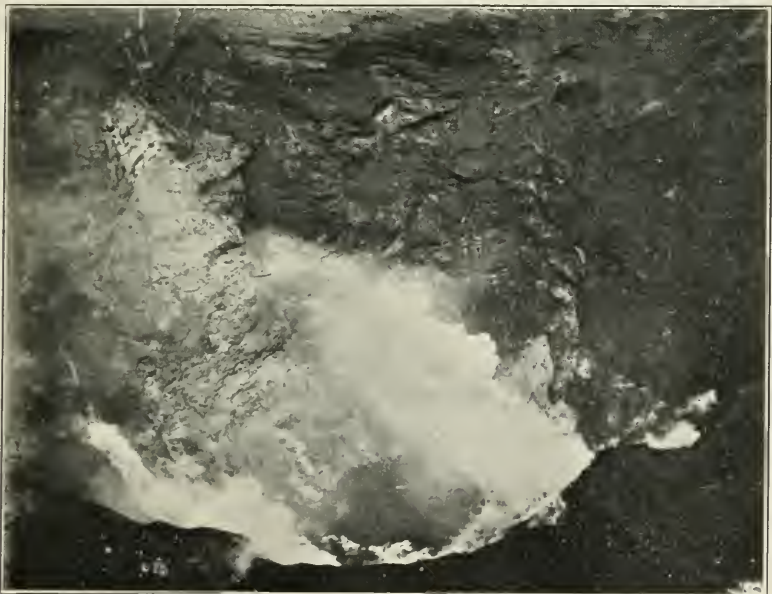


FIG. 6. LOOKING DOWN INTO THE MODERN CRATER OF ASO-SAN, showing the rough layers of mud in the walls and the bottom of one of the vents. Photo by Malcolm Anderson.

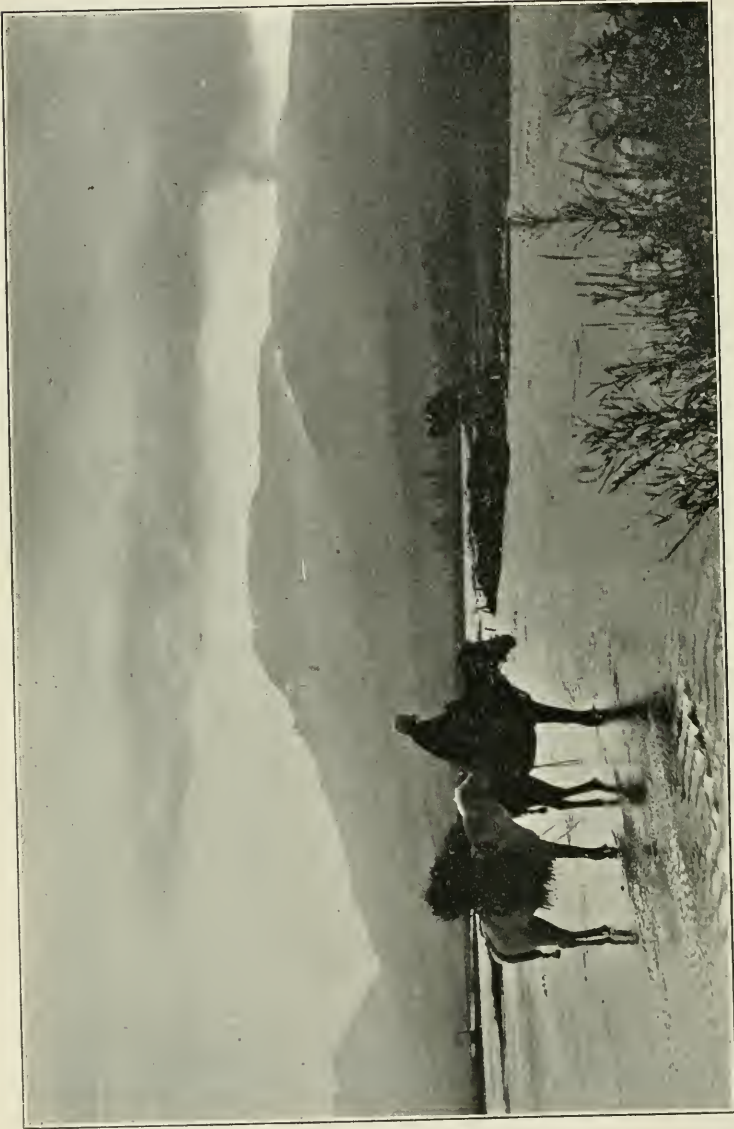


FIG. 7. LOOKING SOUTHEAST FROM THE STREAM ON THE FLOOR OF THE NORTHERN HALF OF THE OLD ASO CRATER OFF TO THE DIVIDING RANGE. A great vapor cloud rises from the new crater on the summit. In the center is Taka-dake, 4000 feet above the foreground, and on the left is part of Neko-dake.

and sulphur vapor and reverberating with explosive roars. This little crater has an oblong shape and is at a rough estimate 900 feet across and 2,000 feet long. Its rim is very uneven, being much higher on the north and east than on the other sides. It is divided into five compartments or vents, each separated from the other by a wall of mud, 100 feet or more high. The two already mentioned are the deepest and the only active ones, and occasionally, when the vapor column diminishes, one can look to the bottom of the northern vent and see the burning sulphur that plasters the lower walls and floor. The bottom is a round flat disc of cracked mud looking like the dried bottom of a pond, and there is no appearance of a hole or conduit descending to greater depths. The other of the two active crater holes is deeper and pours forth more steam. Its bottom can not be seen from any point upon the rim. The yellow sulphur fumes fill the air and become almost unbearable at times when the wind shifts the cloud a little towards one. We were able to follow the edge the whole way round the crater, a distance of about one and one half miles, but the going was difficult on account of the extremely slippery mud that forms the outer sides, which slope sharply away from the precipice on the interior. This soft, fine mud, both outside and inside the crater, is furrowed by rain and given a curious appearance. The other three vents, besides the two already mentioned, lie to the south along the axis of the crater. They are steep-walled, but not so deep as the other ones. They have flat bottoms of cracked mud, though in one the floor at the time of our visit was occupied by a shallow pool of water.

The view from points near the edge of the crater embraces a large part of the northern basin through a gap in the encircling heights on the north. But on all the other sides the rolling summit region is pretty well enclosed and looks a little as if it might have been at one time ages ago the site of a crateral basin much larger than the present active one.

At length the late hour and our extreme thirst after a warm day without water on these dry mountains drove us down from the heights. At the rest house by the temples we obtained a reviving drink of cold spring water, and on the bench where we sat to drink it we left all the change in our possession, which was a total of ten coins, amounting to nine tenths of a cent.

During the memory of man the crater on top of the Aso range has been active, and successive severe eruptions have again and again blown out ashes, cinders and bombs that have darkened the sky for many miles around and covered up the fields, have sent streams of mud mingled with hot water flooding down the mountain sides and over the plain, and caused terrifying noises and shakings of the ground. At such times crops and trees have been blighted and killed by the falling ash or by the heat and vapors, and the streams have been so

filled with débris and poisoned with bitter sulphurous water that the fish have died. Some say that the Shirakawa, which means 'white river,' owes its name to the milky color that it has been known to assume at such times. Loss of life has been occasioned by these outbursts, but the records do not make it clear to what extent. Reference is made in records to fiery rocks sometimes of great size that have been blown out, but lava flows do not seem to have assumed importance. Explosive eruptions of fine débris, as shown by the mud cone, have been predominant during the later history of the volcano.



FIG. 8. RECENT-LOOKING LAVA WITH SMOOTH FLOW STRUCTURE THAT HAS FLOWED DOWN A GULLY HIGH UP ON THE SOUTH SIDE OF NAKA-DAKE. In the distance, far across the great crater of Aso, may be faintly seen the horizon line of the outer wall. The whole foreground is covered with barren volcanic rock.

The greatest eruptions of very recent times were in the winter of 1873 to 1874, when unusual activity continued during several months and ashes covered the ground to a distance of 18 miles; in the winter of 1884, when ashes were blown over Kumamoto, making it so dark there at a distance of 25 miles that lamps had to be used for three days; in 1889, during the year of the Kumamoto earthquake, which was the year following the great explosions of Bandai-san in central Japan; and lastly in 1894, when the floor of the modern crater was somewhat altered.

The problem of old Mount Aso is a deep one. One can not view its gigantic outlines without wondering what forces could have molded them, what could have been the steps in the process of formation of this huge pit, its level floor, its steep walls, the gentle slopes radiating

from its outer rim, and of the rugged mountain bulwark in its center, on the summit of which the life of the volcano has been preserved in a far smaller inner crater. It seems inconceivable that processes alone of building-up could have resulted in such forms as those of Aso; and in attempting to outline its history one always reverts to some theory of destructive action on a very large scale.

The large crater of Aso may have been formed in either one of two ways, by the blowing off and away in some cataclysmic explosion, or series of explosions, the whole mass that must once have filled and overlain the present cavity, or by the sinking in of this same mass and its engulfment in a great void produced by the removal of the material that formerly gave support to the earth's surface at this point. A calculation, such as given below, of the mass displaced in either case affords an impressive sense of the magnitude of the task that was accomplished. The roughly-bedded strata in the walls of the big crater seem to dip away on all sides at a low angle, and their slope is probably reflected in the gently inclined surface of the outer plateau that forms the sides of the Aso cone. From the regularity of these slopes it seems likely that they represent the truncated base of an old conical mountain that continued upward with the present slope to a culminating point high above the center of what is now the crater bowl. It is probable that if such a mountain existed its upper portion rose with a gradually increasing slope into a peak, but even with a constant slope such as now exhibited in the base, its height would have been 7,000 to 7,500 feet above the sea, or about 6,000 feet higher than the present crater floor.

It is probable that during the early history of the volcano such a cone was built up by successive eruptions of lava and fragmental material that formed sheets one upon another down the sides and became roughly stratified in conformity with the slope of the mountain; and that before the close of the period of greatest activity of the volcano this cone was beheaded by some disruptive force. Not only was the summit removed, but the very heart of the volcano was opened, leaving a vast bowl on the site of the old eminence surrounded by the truncated lava flows of the outer circle of the mountain's base. Still later, the processes of building up recommencing, a new mountain was constructed, this time not over a single center as seems to have been the case before, but along the line of the short diameter of the former oval mountain, and in this way the present chain of peaks was raised. But the volcano was gradually dying down, and reconstruction on a grand scale ceased long before the new Aso had reached the dimensions of the old, or even effectually obscured, except to casual observation, the nature of its basal wreck.

The volume of the bowl of Aso, not subtracting the space that is taken up by the supposedly subsequent range, is at least nine cubic



FIG. 9. ONE OF THE MOST ACTIVE VOLCANOES OF JAPAN, KIRISHIMA-YAMA IN SOUTHERN JAPAN. From its summit, which is 6,000 feet high, may be seen Aso-san 70 miles away to the north.

miles. The mass that must once have overlain it, measured as the cone formed by the upward projection of the outer slopes, was at least 28 cubic miles in volume. Thus there must have been removed no less than 37 cubic miles, or about five and a half millions of millions of cubic feet of volcanic rock, a mass equal to over two and a half mountains like Vesuvius.

Furthermore the likelihood that the cone steepened toward its summit makes it possible that the old mountain was of greater size than estimated.

If we conceive of such a vast block of the earth's surface being blown up by some terrific explosion within the volcano, it is natural to suppose that great irregular deposits of the erupted material would be in evidence round the outside of the pit. There are immense areas of volcanic débris that have settled after being blown into the air, whole hills in places, within a radius of many miles of Aso. But these deposits seem to be regularly bedded and not to exhibit the rough and tumble structure that would probably result from their being tumultuously cast up by such a great explosion, and they do not form a rim around the crater rising above the old slopes of the cone. And further the walls of the pit seem to be too regular to have been explosively broken.

More acceptable appears the theory that the Aso crater is a sunken pit. A volcano of such magnitude must certainly have been underlain at some unknown depth by a large body of molten rock, the source of the lava that built up the cone. With all the weight exerted upon it by the overlying rocks and the pressure of steam from within, this fluid or viscous, intensely-heated mass must have sought violently for



KIUSHIU, AS SEEN FROM A DISTANCE. It has been in violent eruption during the last decade.

escape. Having, probably, found one or more points of discharge far below the summit of the cone, it flowed out in such vast quantities that it left a cavity large enough to engulf the whole of the unsupported mountain mass. The sinking was doubtless aided, and lessened in violence, by the partial fusion of the overlying rocks as they became more and more depressed, and probably the action took place around a common center. When the mountain summit had completely disappeared, there was left around about a regular curve of unbroken walls bearing witness to the comparative gentleness with which the action had been carried out. It is possible to consider the central Aso range as part of the old mountain that did not sink or become totally engulfed, but it seems more likely that it is a later growth. The completed work probably left the whole of the sunken mountain melted in a level lake within the great caldron. The radiating lava flows described in a later paragraph may help to account for the material removed.

After nearly two weeks spent in and about Aso we left it, setting out eastward to continue our march across Kiushiu to the Pacific, on the opposite side of the island from our starting point. The less precipitous portions of the crater wall are well-watered and clothed with beautiful groves of pines and cryptomerias, bamboos, oaks and chestnut trees, among which one finds little meadows and mossy places and banks overgrown with rich grass, where thrive an abundance of wild violets of various colors and sweet-smelling daphnes. Through these woods our road wound up out of the pit at a comparatively low and gently-rising portion of the wall, and finally over the crest of the rim to the far-sloping outer reaches. Within a few days more we

looked back at Aso from the top of Sobo-san, the highest mountain in the island, and appreciated more than ever the roundness of the crater and its great size, which can be better grasped from such a distance than from nearer at hand. The square, high block of Taka-dake and the turreted peak of Neko-dake stood impressively out of the huge bowl.

Some miles to the south and east of Aso-san the surface covering of volcanic ejectamenta which has filled up and blotted out the ancient features of the landscape ceases to be a solid sheet, but lava streams continue for great distances beyond, partly burying the old river channels that radiate away from the region occupied by Aso-san. Aso has evidently been the center of all the volcanic activity of this portion of Kiushiu, and the source of supply of the erupted material mantling the region. The longest of the lava arms follows the Gokase river for a distance of over 30 miles beyond the edge of the volcanic sheet as far as the sea, or a total distance of 50 miles from the volcano. It must have started as a broad stream or as successive streams of lava from Aso and have become narrowed into the old canyon of this river. The width of the present lava filling of the canyon is on the average $2\frac{1}{2}$ to 3 miles, and the depth amounts certainly to several hundred feet.

The Gokase-gawa runs to the east coast, and down its canyon we took our course after a few more days in the heart of Kiushiu. The



FIG. 10. OVERLOOKING FROM THE HILLS THE BEAUTIFUL CITY AND BAY OF KAGOSHIMA IN SOUTHERNMOST JAPAN. In the deep bay stands the island volcano Sakura-jima, almost 4,000 feet high, another of the active volcanoes of Kiushiu. In 1863 this city was bombarded and partly burnt by an English admiral and his squadron. Again in 1877 it was set on fire during the last days of the Satsuma rebellion, and here at that time the final desperate stand of some of the Japanese nobility was made against the principle of Europeanization.

scenery was magnificent. High mountains rose on every hand out of the fairly wide and level bottom-land within the canyon. But this was not the old canyon bottom, it was the upper surface of the lava filling. We made this discovery on reaching the middle of the valley, where much to our surprise we came upon a tremendous gorge cut squarely out of it by the river, which is eating its way down again to find its old course. It has already reached a depth of 300 or 400 feet through the lava flow and has left a rift vertically walled on either side by columns of andesite that give a stately beauty to the cliffs. The river rushes down a steep channel, always growing with the addition of little tributaries, which tumble in over the parapet from out of jungles of greenery that overhang the edge and festoon the rocks with drooping purple tassels of wistaria. In its lower course it flows more quietly and widens, the rapids become less frequent and the canyon loses the intensity of its angles. But still the old lava flow continues. From the village of Takeshita, which means "below the falls," we took a rowboat and glided down the broad stream the rest of the way to the sea, away from the wild grandeur of the mountain scenery into the midst of the picturesque landscapes of the Japanese lowland.



CONTROL OF THE COLORADO RIVER REGAINED

BY CHARLES ALMA BYERS

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THE Colorado River, creator of the much-discussed Salton Sea, has at last been captured. Its waters, always of uncertain quantity and consequently often threatening, no longer are poured into Salton Sink by way of a river-like irrigation ditch, but instead flow peaceably into the Gulf of California as in the days before man had tampered with it for irrigation purposes. And incidental to the river's capture, Imperial Valley, that new agricultural region rescued by irrigation from the Colorado Desert, an area lying below the level of the sea, and a region that is some day destined to become worth millions of dollars, is no longer in danger of being inundated by the murky waters of this treacherous "yellow dragon" and consequently wiped practically out of existence.

The going astray of the Colorado River, and the trouble incidental thereto, which was described in *THE POPULAR SCIENCE MONTHLY* some months ago, has occasioned much study and deep concern by engineers all over the country, and has attracted the attention of the heads of two governments—the United States and Mexico. It has created an inland sea in Salton Sink, adjacent to Imperial Valley, that covers about 400 square miles, destroyed the works of the New Liverpool Salt Company, caused three different removals of several miles of the Southern Pacific Railroad, and necessitated the expenditure of many thousands of dollars towards its control, besides threatening to submerge the Imperial Valley, several small cities of considerable importance and a number of rich mineral deposits.

The trouble with the Colorado River, it will be recalled, began in September, 1904. The California Development Company, promoters of the Imperial land colony, needed more water for agricultural purposes than their old irrigation ditch was then supplying, and to remedy the shortage an incision was made in the banks of the river at a point about four miles below the old tapping point, and below the international boundary line between the United States and Mexico. A flood in the river soon cut this new channel so deep as to place the flow beyond control. Gradually this ditch was eroded into a river that at times carried the entire flow of the Colorado River, sometimes amounting to 40,000 second feet of water, and poured it into Salton Sink.

In all, six attempts had been made to capture the runaway river before the last and successful one. The first five, however, were poorly carried out and practically amounted to *nil* in the final success. The sixth proved better, and for a time it seemed to solve the problem. It was completed on November 4, 1906, and on the night of December 7, 1906, during the flood, the river again ate its way through the barrier of willow matting, piles, rocks and dirt and once more wended its way toward Salton Sink. This dam, called the Hind Dam, in honor of the field engineer, Thomas J. Hind, therefore withstood the rebellious-inclined Colorado for a period of only thirty-three days.

The Hind Dam, which, though not a success of itself, aided in the final capture, was a conglomerate creation 170 feet wide at the base, 30 feet across at the top and 35 feet high at the deepest places in the break. It was 3,000 feet in length, of which 600 feet was of rock construction and 2,400 feet of earth and gravel. Its foundation consisted of a heavy, strong mat of willow and cable, held in place by strong piles, about 1,100 in number and from forty to sixty feet in length. The mat was created by the use of 2,200 cords of willow, cut by Indians, 40 miles of five-eighths-inch woven steel cable, and 10,000 cable clips. It was 100 feet wide and 800 feet in length, divided into eighteen sections, and was laid across the river by being uncoiled from a barge floated across the stream.

The piles driven into the mat were also made to serve as a support for a temporary railroad. From this road carload after carload of material was dumped into the gap, in all there being 70,000 tons of rock, 40,000 cubic feet of gravel, 40,000 cubic feet of clay, and 100,000 sacks of sand, besides about 500,000 yards of dirt thrown up by teams and dredges. To carry on this work as many as 1,100 men and 600 horses and mules, besides several steam dredges, shovels, pile drivers and an almost endless string of freight cars, were employed at one time. The cost of the work to the Southern Pacific Railway Company, which, headed by Engineer Epes Randolph, engineered the undertaking, reached an average rate of \$10,000 per day for one hundred days.

The break that occurred in the river after this dam was completed, in December, was at a part about 2,500 feet below the works, and was 1,100 feet wide. Colonel Randolph again assembled his forces, placed E. K. Clark, engineer of the Tucson division of the Southern Pacific Railroad, in direct charge, and work was recommenced to solve this troublesome problem. Another dam, called the Clarke Dam, was built and by it the Colorado River has at last been permanently confined to its old channel.

To build this dam no attempt to follow science was made. The Southern Pacific placed their entire road subject to the orders of the

engineers, and materials of almost every kind were rushed to the break from points far and near as fast as it could be taken care of. Piles were driven, a temporary road was constructed across the break, and there was almost a continual dumping of rock, gravel and dirt into the gap. A carload of material was dumped every seven minutes both day and night, and in the short period of thirteen days 100,000 tons were disposed of, bringing the dam up to water level. Much of this material was hauled a distance of 380 miles.

The Clarke Dam was practically completed February 10, 1906, and the river was declared conquered. The dam proper is 1,200 feet in length, of which 700 feet is of rock and 500 feet of gravel and earth. Work, however, did not cease with the completion of the dam, and, since February 10, several miles of earth embankment have been built to insure permanent success. This work will continue until about sixteen miles of levee is built along the west bank of the river, in addition to the two dams with a combined length of 4,200 feet. The river, in the vicinity of the breaks, or dams, and near the international boundary line, for a distance of about seven miles, flows through a throat only 2,160 feet wide, and is considerably higher than the territory lying to the west. The levee follows the river for this distance, and then swings away to the west towards the Black Buttes, leaving the river below this point to follow its own inclinations.

The California Development Company and the Southern Pacific Railroad Company have expended to date upon this work a sum in excess of \$3,500,000. This is an enormous sum to dump into a river, it seems, but since the river is captured and all interests immune from further trouble, the two companies feel amply rewarded.

The United States government has inaugurated steps to place Imperial Valley in charge of the Government Reclamation Service, but what the outcome of the move will be is not yet known. In the meantime the California Development Company will continue to manage the colony, and will install new head-gates for their irrigation ditches and otherwise improve the system. The farmers of the valley feel secure now for the first time in two years, and Imperial Valley promises to become a prospering community.

THE VALUE OF SCIENCE

SCIENCE AND REALITY

BY M. H. POINCARÉ

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5. *Contingence and Determinism*

I DO not intend to treat here the question of the contingence of the laws of nature, which is evidently insoluble, and on which so much has already been written. I only wish to call attention to what different meanings have been given to this word, contingence, and how advantageous it would be to distinguish them.

If we look at any particular law, we may be certain in advance that it can only be approximative. It is, in fact, deduced from experimental verifications, and these verifications were and could be only approximate. We should always expect that more precise measurements will oblige us to add new terms to our formulas; this is what has happened, for instance, in the case of Marriotte's law.

Moreover the statement of any law is necessarily incomplete. This enunciation should comprise the enumeration of *all* the antecedents in virtue of which a given consequent can happen. I should first describe *all* the conditions of the experiment to be made and the law would then be stated: If all the conditions are fulfilled, the phenomenon will happen.

But we shall be sure of not having forgotten *any* of these conditions only when we shall have described the state of the entire universe at the instant t ; all the parts of this universe may, in fact, exercise an influence more or less great on the phenomenon which must happen at the instant $t + dt$.

Now it is clear that such a description could not be found in the enunciation of the law; besides, if it were made, the law would become incapable of application; if one required so many conditions, there would be very little chance of their ever being all realized at any moment.

Then as one can never be certain of not having forgotten some essential condition, it can not be said: If such and such conditions are realized, such a phenomenon will occur; it can only be said: If such and such conditions are realized, it is probable that such a phenomenon will occur, very nearly.

Take the law of gravitation, which is the least imperfect of all known laws. It enables us to foresee the motions of the planets. When I use it, for instance, to calculate the orbit of Saturn, I neglect the action of the stars, and in doing so, I am certain of not deceiving myself, because I know that these stars are too far away for their action to be sensible.

I announce, then, with a quasi-certitude that the coordinates of Saturn at such an hour will be comprised between such and such limits. Yet is that certitude absolute? Could there not exist in the universe some gigantic mass, much greater than that of all the known stars and whose action could make itself felt at great distances? That mass might be animated by a colossal velocity, and after having circulated from all time at such distances that its influence had remained hitherto insensible to us, it might come all at once to pass near us. Surely it would produce in our solar system enormous perturbations that we could not have foreseen. All that can be said is that such an event is wholly improbable, and then, instead of saying: Saturn will be near such a point of the heavens, we must limit ourselves to saying: Saturn will probably be near such a point of the heavens. Although this probability may be practically equivalent to certainty, it is only a probability.

For all these reasons, no particular law will ever be more than approximate and probable. Scientists have never failed to recognize this truth; only they believe, right or wrong, that every law may be replaced by another closer and more probable, that this new law will itself be only provisional, but that the same movement can continue indefinitely, so that science in progressing will possess laws more and more probable, that the approximation will end by differing as little as you choose from exactitude and the probability from certitude.

If the scientists who think thus were right, must it still be said that *the* laws of nature are contingent, even though *each* law, taken in particular, may be qualified as contingent? Or must one require, before concluding the contingency of *the* natural laws, that this progress have an end, that the scientist finish some day by being arrested in his search for a closer and closer approximation and that, beyond a certain limit, he thereafter meet in nature only caprice?

In the conception of which I have just spoken (and which I shall call the scientific conception), every law is only a statement, imperfect and provisional, but it must one day be replaced by another, a superior law, of which it is only a crude image. No place therefore remains for the intervention of a free will.

It seems to me that the kinetic theory of gases will furnish us a striking example.

You know that in this theory all the properties of gases are ex-

plained by a simple hypothesis; it is supposed that all the gaseous molecules move in every direction with great velocities and that they follow rectilinear paths which are disturbed only when one molecule passes very near the sides of the vessel or another molecule. The effects our crude senses enable us to observe are the mean effects, and in these means, the great deviations compensate, or at least it is very improbable that they do not compensate; so that the observable phenomena follow simple laws such as that of Mariotte or of Gay-Lussac. But this compensation of deviations is only probable. The molecules incessantly change place and in these continual displacements the figures they form pass successively through all possible combinations. Singly these combinations are very numerous; almost all are in conformity with Mariotte's law, only a few deviate from it. These also will happen, only it would be necessary to wait a long time for them. If a gas were observed during a sufficiently long time, it would certainly be finally seen to deviate, for a very short time, from Mariotte's law. How long would it be necessary to wait? If it were desired to calculate the probable number of years, it would be found that this number is so great that to write only the number of places of figures employed would still require half a score places of figures. No matter; enough that it may be done.

I do not care to discuss here the value of this theory. It is evident that if it be adopted, Mariotte's law will thereafter appear only as contingent, since a day will come when it will not be true. And yet, think you the partisans of the kinetic theory are adversaries of determinism? Far from it; they are the most ultra of mechanists. Their molecules follow rigid paths, from which they depart only under the influence of forces which vary with the distance, following a perfectly determinate law. There remains in their system not the smallest place either for freedom, or for an evolutionary factor, properly so-called, or for anything whatever that could be called contingency. I add, to avoid mistake, that neither is there any evolution of Mariotte's law itself; it ceases to be true after I know not how many centuries; but at the end of a fraction of a second it again becomes true and that for an incalculable number of centuries.

And since I have pronounced the word evolution, let us clear away another mistake. It is often said: Who knows whether the laws do not evolve and whether we shall not one day discover that they were not at the Carboniferous epoch what they are to-day? What are we to understand by that? What we think we know about the past state of our globe, we deduce from its present state. And how is this deduction made? It is by means of laws supposed known. The law being a relation between the antecedent and the consequent, enables us equally well to deduce the consequent from the antecedent, that is, to

foresee the future, and to deduce the antecedent from the consequent, that is, to conclude from the present to the past. The astronomer who knows the present situation of the stars can from it deduce their future situation by Newton's law, and this is what he does when he constructs ephemerides; and he can equally deduce from it their past situation. The calculations he thus can make can not teach him that Newton's law will cease to be true in the future, since this law is precisely his point of departure; not more can they tell him it was not true in the past. Still in what concerns the future, his ephemerides can one day be tested and our descendants will perhaps recognize that they were false. But in what concerns the past, the geologic past which had no witnesses, the results of his calculation, like those of all speculations where we seek to deduce the past from the present, escape by their very nature every species of test. So that if the laws of nature were not the same in the Carboniferous age as at the present epoch, we shall never be able to know it, since we can know nothing of this age only what we deduce from the hypothesis of the permanence of these laws.

Perhaps it will be said that this hypothesis might lead to contradictory results and that we shall be obliged to abandon it. Thus, in what concerns the origin of life, we may conclude that there have always been living beings, since the present world shows us always life springing from life; and we may also conclude that there have not always been, since the application of the existent laws of physics to the present state of our globe teaches us that there was a time when this globe was so warm that life on it was impossible. But contradictions of this sort can always be removed in two ways; it may be supposed that the actual laws of nature are not exactly what we have assumed; or else it may be supposed that the laws of nature actually are what we have assumed, but that it has not always been so.

It is evident that the actual laws will never be sufficiently well known for us not to be able to adopt the first of these two solutions and for us to be constrained to infer the evolution of natural laws.

On the other hand, suppose such an evolution; assume, if you wish, that humanity lasts sufficiently long for this evolution to have witnesses. The *same* antecedent shall produce, for instance, different consequents at the Carboniferous epoch and at the Quaternary. That evidently means that the antecedents are closely alike; if all the circumstances were identical, the Carboniferous epoch would be indistinguishable from the Quaternary. Evidently this is not what is supposed. What remains is that such antecedent, accompanied by such accessory circumstance, produces such consequent; and that the same antecedent, accompanied by such other accessory circumstance, produces such other consequent. Time does not enter into the affair.

The law, such as ill-informed science would have stated it, and which would have affirmed that this antecedent always produces this consequent, without taking account of the accessory circumstances, this law, which was only approximate and probable, must be replaced by another law more approximate and more probable, which brings in these accessory circumstances. We always come back, therefore, to that same process which we have analyzed above, and if humanity should discover something of this sort, it would not say that it is the laws which have evolved, but the circumstances which have changed.

Here, therefore, are several different senses of the word contingency. M. LeRoy retains them all and he does not sufficiently distinguish them, but he introduces a new one. Experimental laws are only approximate, and if some appear to us as exact, it is because we have artificially transformed them into what I have above called a principle. We have made this transformation freely, and as the caprice which has determined us to make it is something eminently contingent, we have communicated this contingency to the law itself. It is in this sense that we have the right to say that determinism supposes freedom, since it is freely that we become determinists. Perhaps it will be found that this is to give large scope to nominalism and that the introduction of this new sense of the word contingency will not help much to solve all those questions which naturally arise and of which we have just been speaking.

I do not at all wish to investigate here the foundations of the principle of induction; I know very well that I shall not succeed; it is as difficult to justify this principle as to get on without it. I only wish to show how scientists apply it and are forced to apply it.

When the same antecedent recurs, the same consequent must likewise recur; such is the ordinary statement. But reduced to these terms this principle could be of no use. For one to be able to say that the same antecedent recurred, it would be necessary for the circumstances *all* to be reproduced, since no one is absolutely indifferent, and for them to be *exactly* reproduced. And, as that will never happen, the principle can have no application.

We should therefore modify the enunciation and say: If an antecedent A has once produced a consequent B , an antecedent A' , slightly different from A , will produce a consequent B' , slightly different from B . But how shall we recognize that the antecedents A and A' are "slightly different"? If some one of the circumstances can be expressed by a number, and this number has in the two cases values very near together, the sense of the phrase "slightly different" is relatively clear; the principle then signifies that the consequent is a continuous function of the antecedent. And as a practical rule, we reach this conclusion that we have the right to interpolate. This

is in fact what scientists do every day, and without interpolation all science would be impossible.

Yet observe one thing. The law sought may be represented by a curve. Experiment has taught us certain points of this curve. In virtue of the principle we have just stated, we believe these points may be connected by a continuous graph. We trace this graph with the eye. New experiments will furnish us new points of the curve. If these points are outside of the graph traced in advance, we shall have to modify our curve, but not to abandon our principle. Through any points, however numerous they may be, a continuous curve may always be passed. Doubtless, if this curve is too capricious, we shall be shocked (and we shall even suspect errors of experiment), but the principle will not be directly put at fault.

Furthermore, among the circumstances of a phenomenon, there are some that we regard as negligible, and we shall consider A and A' as slightly different if they differ only by these accessory circumstances. For instance, I have ascertained that hydrogen unites with oxygen under the influence of the electric spark, and I am certain that these two gases will unite anew, although the longitude of Jupiter may have changed considerably in the interval. We assume, for instance, that the state of distant bodies can have no sensible influence on terrestrial phenomena, and that seems in fact requisite, but there are cases where the choice of these practically indifferent circumstances admits of more arbitrariness or, if you choose, requires more fact.

One more remark: The principle of induction would be inapplicable if there did not exist in nature a great quantity of bodies like one another, or almost alike, and if we could not infer, for instance, from one bit of phosphorus to another bit of phosphorus.

If we reflect on these considerations, the problem of determinism and of contingency will appear to us in a new light.

Suppose we were able to embrace the series of all phenomena of the universe in the whole sequence of time. We could envisage what might be called the *sequences*, I mean relations between antecedent and consequent. I do not wish to speak of constant relations or laws, I envisage separately (individually, so to speak) the different sequences realized.

We should then recognize that among these sequences there are no two altogether alike. But, if the principle of induction, as we have just stated it, is true, there will be those almost alike and that can be classed alongside one another. In other words, it is possible to make a classification of sequences.

It is to the possibility and the legitimacy of such a classification that determinism, in the end, reduces. This is all that the preceding analysis leaves of it. Perhaps under this modest form it will seem less appalling to the moralist.

It will doubtless be said that this is to come back by a detour to M. LeRoy's conclusion which a moment ago we seemed to reject: we are determinists voluntarily. And in fact all classification supposes the active intervention of the classifier. I agree that this may be maintained, but it seems to me that this detour will not have been useless and will have contributed to enlighten us a little.

6. *Objectivity of Science*

I arrive at the question set by the title of this article: What is the objective value of science? And first what should we understand by objectivity?

What guarantees the objectivity of the world in which we live is that this world is common to us with other thinking beings. Through the communications that we have with other men, we receive from them ready-made reasonings; we know that these reasonings do not come from us and at the same time we recognize in them the work of reasonable beings like ourselves. And as these reasonings appear to fit the world of our sensations, we think we may infer that these reasonable beings have seen the same thing as we; thus it is we know we have not been dreaming.

Such, therefore, is the first condition of objectivity; what is objective must be common to many minds and consequently transmissible from one to the other, and as this transmission can only come about by that "discourse" which inspires so much distrust in M. LeRoy, we are even forced to conclude: no discourse, no objectivity.

The sensations of others will be for us a world eternally closed. We have no means of verifying that the sensation I call red is the same as that which my neighbor calls red.

Suppose that a cherry and a red poppy produce on me the sensation *A* and on him the sensation *B* and that, on the contrary, a leaf produces on me the sensation *B* and on him the sensation *A*. It is clear we shall never know anything about it; since I shall call red the sensation *A* and green the sensation *B*, while he will call the first green and the second red. In compensation, what we shall be able to ascertain is that, for him as for me, the cherry and the red poppy produce the *same* sensation, since he gives the same name to the sensations he feels and I do the same.

Sensations are therefore intransmissible, or rather all that is pure quality in them is intransmissible and forever impenetrable. But it is not the same with relations between these sensations.

From this point of view, all that is objective is devoid of all quality and is only pure relation. Certes, I shall not go so far as to say that objectivity is only pure quantity (this would be to particularize too far the nature of the relations in question), but we understand

how some one could have been carried away into saying that the world is only a differential equation.

With due reserve regarding this paradoxical proposition, we must nevertheless admit that nothing is objective which is not transmissible, and consequently that the relations between the sensations can alone have an objective value.

Perhaps it will be said that the esthetic emotion, which is common to all mankind, is proof that the qualities of our sensations are also the same for all men and hence are objective. But if we think about this, we shall see that the proof is not complete; what is proved is that this emotion is aroused in John as in James by the sensations to which James and John give the same name or by the corresponding combinations of these sensations; either because this emotion is associated in John with the sensation *A*, which John calls red, while parallelly it is associated in James with the sensation *B*, which James calls red; or better because this emotion is aroused, not by the qualities themselves of the sensations, but by the harmonious combination of their relations of which we undergo the unconscious impression.

Such a sensation is beautiful, not because it possesses such a quality, but because it occupies such a place in the woof of our associations of ideas, so that it can not be excited without putting in motion the 'receiver' which is at the other end of the thread and which corresponds to the artistic emotion.

Whether we take the moral, the esthetic or the scientific point of view, it is always the same thing. Nothing is objective except what is identical for all; now we can only speak of such an identity if a comparison is possible, and can be translated into a 'money of exchange' capable of transmission from one mind to another. Nothing, therefore, will have objective value except what is transmissible by 'discourse,' that is, intelligible.

But this is only one side of the question. An absolutely disordered aggregate could not have objective value since it would be unintelligible, but no more can a well-ordered assemblage have it, if it does not correspond to sensations really experienced. It seems to me superfluous to recall this condition, and I should not have dreamed of it, if it had not lately been maintained that physics is not an experimental science. Although this opinion has no chance of being adopted either by physicists or by philosophers, it is well to be warned so as not to let oneself slip over the declivity which would lead thither. Two conditions are therefore to be fulfilled, and if the first separates reality² from the dream, the second distinguishes it from the romance.

² I here use the word real as a synonym of objective; I thus conform to common usage; perhaps I am wrong, our dreams are real, but they are not objective.

Now what is science? I have explained in the preceding article, it is before all a classification, a manner of bringing together facts which appearances separate, though they were bound together by some natural and hidden kinship. Science, in other words, is a system of relations. Now we have just said, it is in the relations alone that objectivity must be sought; it would be vain to seek it in beings considered as isolated from one another.

To say that science can not have objective value since it teaches us only relations, this is to reason backwards, since, precisely, it is relations alone which can be regarded as objective.

External objects, for instance, for which the word *object* was invented, are really *objects* and not fleeting and fugitive appearances, because they are not only groups of sensations, but groups cemented by a constant bond. It is this bond, and this bond alone, which is the object in itself, and this bond is a relation.

Therefore, when we ask what is the objective value of science, that does not mean: Does science teach us the true nature of things? but it means: Does it teach us the true relations of things?

To the first question, no one would hesitate to reply, no; but I think we may go farther; not only science can not teach us the nature of things; but nothing is capable of teaching it to us and if any god knew it, he could not find words to express it. Not only can we not divine the response, but if it were given to us, we could understand nothing of it; I ask myself even whether we really understand the question.

When, therefore, a scientific theory pretends to teach us what heat is, or what is electricity, or life, it is condemned beforehand; all it can give us is only a crude image. It is, therefore, provisional and crumbling.

The first question being out of reason, the second remains. Can science teach us the true relations of things? What it joins together should that be put asunder, what it puts asunder should that be joined together?

To understand the meaning of this new question, it is needful to refer to what was said above on the conditions of objectivity. Have these relations an objective value? That means: Are these relations the same for all? Will they still be the same for those who shall come after us?

It is clear that they are not the same for the scientist and the ignorant person. But that is unimportant, because if the ignorant person does not see them all at once, the scientist may succeed in making him see them by a series of experiments and reasonings. The thing essential is that there are points on which all those acquainted with the experiments made can reach accord.

The question is to know whether this accord will be durable and whether it will persist for our successors. It may be asked whether the unions that the science of to-day makes will be confirmed by the science of to-morrow. To affirm that it will be so we can not invoke any *a priori* reason; but this is a question of fact, and science has already lived long enough for us to be able to find out by asking its history whether the edifices it builds stand the test of time, or whether they are only ephemeral constructions.

Now what do we see? At the first blush it seems to us that the theories last only a day and that ruins upon ruins accumulate. To-day the theories are born, to-morrow they are the fashion, the day after to-morrow they are classic, the fourth day they are superannuated, and the fifth they are forgotten. But if we look more closely, we see that what thus succumb are the theories, properly so called, those which pretend to teach us what things are. But there is in them something which usually survives. If one of them has taught us a true relation, this relation is definitively acquired, and it will be found again under a new disguise in the other theories which will successively come to reign in place of the old.

Take only a single example: The theory of the undulations of the ether taught us that light is a motion; to-day fashion favors the electromagnetic theory which teaches us that light is a current. We do not consider whether we could reconcile them and say that light is a current, and that this current is a motion. As it is probable in any case that this motion would not be identical with that which the partisans of the old theory presume, we might think ourselves justified in saying that this old theory is dethroned. And yet something of it remains, since between the hypothetical currents which Maxwell supposes there are the same relations as between the hypothetical motions that Fresnel supposed. There is, therefore, something which remains over and this something is the essential. This it is which explains how we see the present physicists pass without any embarrassment from the language of Fresnel to that of Maxwell. Doubtless many connections that were believed well established have been abandoned, but the greatest number remain and it would seem must remain.

And for these, then, what is the measure of their objectivity? Well, it is precisely the same as for our belief in external objects. These latter are real in this, that the sensations they make us feel appear to us as united to each other by I know not what indestructible cement and not by the hazard of a day. In the same way science reveals to us between phenomena other bonds finer but not less solid; these are threads so slender that they long remained unperceived, but once noticed there remains no way of not seeing them; they are therefore not less real than those which give their reality to external objects; small

matter that they are more recently known since neither can perish before the other.

It may be said, for instance, that the ether is no less real than any external body; to say this body exists is to say there is between the color of this body, its taste, its smell, an intimate bond, solid and persistent; to say the ether exists is to say there is a natural kinship between all the optical phenomena, and neither of the two propositions has less value than the other.

And the scientific syntheses have in a sense even more reality than those of the ordinary senses, since they embrace more terms and tend to absorb in them the partial syntheses.

It will be said that science is only a classification and that a classification can not be true, but convenient. But it is true that it is convenient, it is true that it is so not only for me, but for all men; it is true that it will remain convenient for our descendants; it is true finally that this can not be by chance.

In sum, the sole objective reality consists in the relations of things whence results the universal harmony. Doubtless these relations, this harmony, could not be conceived outside of a mind which conceives them. But they are nevertheless objective because they are, will become, or will remain, common to all thinking beings.

This will permit us to revert to the question of the rotation of the earth which will give us at the same time a chance to make clear what precedes by an example.

7. *The Rotation of the Earth*

“. . . Therefore,” have I said in *Science and Hypothesis*, “this affirmation, the earth turns round, has no meaning . . . or rather these two propositions, the earth turns round, and, it is more convenient to suppose that the earth turns round, have one and the same meaning.”

These words have given rise to the strangest interpretations. Some have thought they saw in them the rehabilitation of Ptolemy's system, and perhaps the justification of Galileo's condemnation.

Those who had read attentively the whole volume could not, however, delude themselves. This truth, the earth turns round, was put on the same footing as Euclid's postulate, for example. Was that to reject it? But better; in the same language it may very well be said: These two propositions, the external world exists, or, it is more convenient to suppose that it exists, have one and the same meaning. So the hypothesis of the rotation of the earth would have the same degree of certitude as the very existence of external objects.

But after what we have just explained in the fourth part, we may go farther. A physical theory, we have said, is by so much the more

true, as it puts in evidence more true relations. In the light of this new principle, let us examine the question which occupies us.

No, there is no absolute space; these two contradictory propositions: 'The earth turns round' and 'The earth does not turn round' are, therefore, neither of them more true than the other. To affirm one while denying the other, *in the kinematic sense*, would be to admit the existence of absolute space.

But if the one reveals true relations that the other hides from us, we can nevertheless regard it as physically more true than the other, since it has a richer content. Now in this regard no doubt is possible.

Behold the apparent diurnal motion of the stars, and the diurnal motion of the other heavenly bodies, and besides, the flattening of the earth, the rotation of Foucault's pendulum, the gyration of cyclones, the trade-winds, what not else? For the Ptolemaist all these phenomena have no bond between them; for the Copernican they are produced by the one same cause. In saying, the earth turns round, I affirm that all these phenomena have an intimate relation, and *that is true*, and that remains true, although there is not and can not be absolute space.

So much for the rotation of the earth upon itself; what shall we say of its revolution around the sun? Here again, we have three phenomena which for the Ptolemaist are absolutely independent and which for the Copernican are referred back to the same origin; they are the apparent displacements of the planets on the celestial sphere, the aberration of the fixed stars, the parallax of these same stars. Is it by chance that all the planets admit an inequality whose period is a year, and that this period is precisely equal to that of aberration, precisely equal besides to that of parallax? To adopt Ptolemy's system is to answer, yes; to adopt that of Copernicus is to answer, no; this is to affirm that there is a bond between the three phenomena and that also is true although there is no absolute space.

In Ptolemy's system, the motions of the heavenly bodies can not be explained by the action of central forces, celestial mechanics is impossible. The intimate relations that celestial mechanics reveals to us between all the celestial phenomena are true relations; to affirm the immobility of the earth would be to deny these relations, that would be to fool ourselves.

The truth for which Galileo suffered remains, therefore, the truth, although it has not altogether the same meaning as for the vulgar, and its true meaning is much more subtle, more profound and more rich.

8. *Science for Its Own Sake*

Not against M. LeRoy do I wish to defend science for its own sake; may be this is what he condemns, but this is what he cultivates, since

he loves and seeks truth and could not live without it. But I have some thoughts to express.

We can not know all facts and it is necessary to choose those which are worthy of being known. According to Tolstoi, scientists make this choice at random, instead of making it, which would be reasonable, with a view to practical applications. On the contrary, scientists think that certain facts are more interesting than others, because they complete an unfinished harmony, or because they make one foresee a great number of other facts. If they are wrong, if this hierarchy of facts that they implicitly postulate is only an idle illusion, there could be no science for its own sake, and consequently there could be no science. As for me, I believe they are right, and, for example, I have shown above what is the high value of astronomical facts, not because they are capable of practical applications, but because they are the most instructive of all.

It is only through science and art that civilization is of value. Some have wondered at the formula: science for its own sake; and yet it is as good as life for its own sake, if life is only misery; and even as happiness for its own sake, if we do not believe that all pleasures are of the same quality, if we do not wish to admit that the goal of civilization is to furnish alcohol to people who love to drink.

Every act should have an aim. We must suffer, we must work, we must pay for our place at the game, but this is for seeing's sake; or at the very least that others may one day see.

All that is not thought is pure nothingness; since we can think only thought and all the words we use to speak of things can express only thoughts, to say there is something other than thought, is therefore an affirmation which can have no meaning.

And yet—strange contradiction for those who believe in time—geologic history shows us that life is only a short episode between two eternities of death, and that, even in this episode, conscious thought has lasted and will last only a moment. Thought is only a gleam in the midst of a long night.

But it is this gleam which is everything.

THE NEWER HYGIENE¹

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INSTRUCTION in the nature of infectious diseases, especially in the means of transmitting these diseases from one person to another, is required by law in all our public schools. This law is of great value; for it is only through the intelligent cooperation of a well-informed public, that hygienic and sanitary measures designed to control and stamp out infectious diseases can be successful. A wide diffusion of this knowledge will go far to make tuberculosis a thing of the past, and diphtheria and small-pox unknown.

In obedience to the legal requirement, there are taught, in our public schools, certain elementary facts regarding the nature of pathogenic bacteria, and certain facts regarding the ways in which they are transmitted from one person to another. These facts in themselves are of inestimable value. But they are insufficient.

The presence of bacteria within or upon the human body, the transmission of disease-germs from the sick to the well, is but one of the factors tending to cause disease. To acquire a disease it is necessary, not only to acquire the germs of that disease, but there usually must be a lowering of bodily resistance as well.

Every fourth person in this room is carrying daily in his throat and mouth virulent pneumococci. Yet he does not acquire pneumonia. And why? Because there is an efficient defense against this disease in the healthy human body. Some day this defense will be lowered and pneumonia develop. Most soldiers in the Philippines carry in their intestinal canals virulent germs of dysentery; and with no ill effects, till intoxication or dietary excesses lower the intestinal resistance. We daily inhale germs of tuberculosis. Some day, when our resistance is low, we acquire the disease.

A knowledge of the body's fighting power against bacteria, a knowledge of the ways in which that power can be increased or decreased by hereditary influences and by modes of life, is therefore of hygienic importance, and should form part of the curriculum of every public school.

The body fights disease in many ways. It will be sufficient for hygienic purposes to teach but three of these ways: the method of antitoxines, the method of antiseptics and the method of phagocytosis.

¹An address before the Indiana Academy of Science, at Indianapolis, December 1, 1906.

There are many diseases in which the symptoms are caused, not by the bacteria themselves, but by the chemical poisons the bacteria manufacture. Thus, in tetanus, or lock-jaw, the bacteria grow, perhaps unnoticed, at the bottom of the Fourth-of-July wound on the hand or foot; but the chemical poisons they manufacture, carried by the blood to the brain and spinal cord, cause the spasms and convulsions that characterize the disease. In diphtheria, the bacteria rarely enter the body, but grow in grayish-white masses on the moist surfaces of the mouth and throat. The chemical poisons they manufacture, absorbed by the tissues, cause the paralysis and heart failure that characterize the disease.

The body has the power of forming substances that neutralize these poisons. To these neutralizing substances the name antitoxine has been given.

This fact is of hygienic importance for two reasons. First, because it is sometimes possible to assist the body in its efforts to form antitoxines, by introducing into it antitoxines artificially prepared; and, second, because the body's power to form these substances is modified by mode of life. A horse that has been repeatedly injected with poison manufactured by the germs of diphtheria growing on an artificial culture medium, develops enormous amounts of diphtheria antitoxine. A few drops of its serum will render harmless large quantities of diphtheria poison.¹ Overwork, insufficient clothing, improper food, alcoholic excesses, lack of sleep, and other factors, so lower the antitoxine-forming power of the human body, as to greatly increase the dangers from infection.

The second way of hygienic importance in which the body fights disease is by the formation of chemical substances that, although they have no influence on the poisons manufactured by bacteria, have an even more important property, that of killing the bacteria themselves. The presence of these antiseptic, or bacteria-killing substances in the blood and tissue juices is easily shown. One has but to mix bacteria with serum, and test, from time to time, by simply cultural methods,² whether or not the bacteria are alive. Thus, in one experiment, there were mixed with human serum germs of typhoid fever in such numbers that every drop of the serum contained 50,000 bacteria. Two minutes later, but 20,000 of these were alive; at the end of ten minutes, but 800; and in twenty-five minutes, they were all dead.

Not only can serum kill bacteria, but most of the secretions of the healthy human body are bacteria-killing as well. Gastric juice, vaginal secretion and nasal secretion, kill bacteria in enormous numbers. The

¹ Through the use of diphtheria antitoxine in practical medicine the mortality from diphtheria has been reduced from the 24 per cent. to 40 per cent. it was, twenty years ago, to the less than 1 per cent. it now is, in well-treated cases.

² See POPULAR SCIENCE MONTHLY, Vol. 66, pp. 474-477.

hygienic significance of this is evident from the fact that these bacteria-killing substances, also, are modified by modes of life. Dietary excesses may so lower the bacteria-killing properties of gastric juice, and unsanitary conditions so lessen that of tissue juices, that susceptibility to infectious diseases is greatly increased.

The third way of hygienic importance in which the body fights disease is by phagocytosis. In the body there are millions of white blood corpuscles, each having the power of independent motion and as one of its functions the faculty of eating and destroying disease germs.

It is found that the bacteria-eating power of white corpuscles is largely dependent upon certain chemical substances³ present in the blood and tissue juices. Without these substances, the eating of certain pathogenic bacteria does not take place. With them, it is very active. It is further found that these chemical substances are influenced by modes of life. That they may be increased or decreased under different hygienic conditions. Phagocytosis, therefore, has also a place in popular hygienic knowledge.

One of the unfortunate results of the spread of knowledge of pathogenic microorganisms is the formation of an unreasoning popular fear of disease germs. It is thought that a wide understanding of facts regarding bodily resistance will tend to replace this unfortunate germ-fear by a rational faith in the body's marvelous powers. That it may turn the tide of hygienic endeavor from an exclusive fight against bacteria to a combined fight *against* bacteria and *for* bodily resistance.

³ Opsonins.

THE FORMS OF SELECTION WITH REFERENCE TO THEIR APPLICATION TO MAN

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WHAT is the importance of natural selection in mankind is a question often asked. It is about as often answered without analysis. Put in this very general way, it contains, and confuses, several different questions.

It is alleged that the conditions of life are so much improved by civilization that the struggle for existence is vanishing. Is that struggle, then, the only means of selection? And even if the cruder forms of selection are coming to be of little importance in man—which is doubtless the fact—are there not other kinds of selection still to be considered? It is time to analyze selection and determine its species. Then, when we know the kinds of selection, we may ask, with specific reference to each particular one: What is *its* importance in the present evolution of man? How far is each kind of selection operative in civilized society?

In our task of classification, let us consider first Darwin's division. By his choice of a name for natural selection, Darwin assigns to nature a work analogous to that of the breeder of domestic animals. Natural and artificial are therefore two kinds or species of selection. The latter species is more definitely named breeder's selection. Thus we obtain a first and provisional classification of the forms of selection as

NATURAL SELECTION AND BREEDER'S SELECTION

This simple classification is of importance, rather for an understanding of the meaning of the term natural selection, as Darwin thought of it, than for our particular purposes. But we need to dwell upon it somewhat, and dispose of it, before attempting a more adequate analysis.

The analogy from which the term natural selection is derived suggests a personification of nature. But natural selection is explicitly contrasted with conscious and personal factors.¹ Nature's action is

¹ Though requiring such a *caveat*, Darwin's use of the term "natural selection" is a just and appropriate development in the meaning of the words. A possible wrong first impression is corrected by the most elementary knowledge of the subject. Not as much can be said for the proposed alternative, "survival of the fittest." The "fittest" can not well be further defined than as the fittest to survive. Thus we get back to mere survival. What we need to add to this

impersonal and unconscious. It is not choice. Breeder's selection, on the other hand, is consciously directed towards a known and very definite end, the chosen "points." The action of natural selection is no more conscious than is the action of the current of water that separates pebbles from sand. This is the first great difference between natural selection and breeder's selection.

In another respect nature's agency in selection differs fundamentally from that of the breeder. The mode of operation of breeder's selection is positive; that of natural selection is negative. Natural selection eliminates by death the less well adapted members of a species. The better adapted survive and reproduce their kind. It does not matter in what respect they are better adapted. Protection from enemies is achieved in the case of the porcupine by his quills. The deer is saved by fleetness; wild cattle by the herding instinct, and by the effective use of horns and hoofs which that makes possible. No particular sort of quality is favored by natural selection, but those lacking in any respect are cut off. Nature has no plan. The line of evolution may take any direction; only, whatever the direction of improvement, woe to the hindmost. We have already seen that breeder's selection is conscious. That means its action is also positive. Attention is directed to reproducing and further evolving a favored type. The fan-tail pigeon exists because breeder's sought to develop a type with an unusually large number of tail feathers. The fleece of the better breeds of sheep has become fine and long because breeders sought this particular result. Breeder's selection positively favors certain individuals and types. Natural selection is primarily destructive of the inferior. It is negative. Incidentally it allows certain better adapted individuals to survive.

The third difference between natural selection and breeder's selection is that the latter operates directly on propagation, not necessarily by death. In "nature," this is among wild animals, the capacity to survive is the whole story. It may in general be assumed that a wild animal that survives to maturity, and lives through its prime, will reproduce its kind. Though it is the essential point always, propagation is not in general the crucial point with lower animals.² Among

is the notion of selection. Survival involving selection is the thing of interest to the biologist and sociologist. The word "fittest" is often used as if it meant "best," or at any rate most complex and most highly organized. It is particularly in its application to man that this reading of an ethical connotation into the "survival of the fittest" is to be deprecated.

The words "natural selection," whatever may have been the force of the objection at the introduction of the term, have now quite lost any suggestion of purpose and choice. Even the single word selection is coming to be used and understood as a generic term for natural selection, breeder's selection, "social selection"—if there be such a thing—and for any other forms of selection.

² For some it is in part, that is, in sexual selection.

domestic animals, on the other hand, mere survival is not enough. Where the breeder intervenes, propagation becomes the critical point. The breeder can use inferior cattle as draft animals. He favors some definite type for reproduction, but rejected individuals are not therefore destroyed. They may be put to some other use. Breeder's selection has, as we shall come to see, the character of reproductive selection. What Darwin, for the most part, dealt with as natural selection, we shall find it better to call lethal selection.

The root-idea of natural selection, and of selection in general, is segregation into classes distinguished by differences as regards continued existence of the type. One type is better adapted and survives, another is eliminated. Selection means, etymologically, a picking out and setting apart.³ It is isolation in breeding. One eminent biologist and evolutionist, Romanes, would substitute this, as the more general term, for natural selection, and would make the latter but a species of isolation. If a superior type is to be evolved and preserved, breeding must be confined to those possessing in high degree the characteristics of that type. The most direct and sure way to isolate the fit and to prevent the propagation of unfit types is to kill off the unfit individuals. This is just what "nature" does. But there are other ways of attaining the same goal.

Darwin never attempted a formal classification of the forms of selection. He does name, and treat at length, one other form besides natural selection, that is, sexual selection. Other kinds, which are of comparatively little importance in subhuman species, he either altogether fails to distinguish or touches only casually. By his use of the term sexual selection, which he contrasts with "ordinary"⁴ or natural selection, he does imply that the word selection is, by destiny, if not by established usage, a generic term, to be qualified by an adjective in order to indicate the various species of selection.

THE FOUR KINDS OF SELECTION

We have now come to the distinctive purpose of this essay, that is a classification of the forms of selection having general applicability. I believe that adequate analysis—of course from the point of view of the sociologist, which is at the same time the most general point of view—gives us four species of selection, named as follows:

Lethal selection.

Sexual selection.

Reproductive selection.

Group selection.

These terms, some of which are already familiar, are now to be defined.

³ Selection, by usage, is both the process and the result. And of the parts or aspects of the result, it is both negative (elimination) and positive (survival).

⁴ Cf. "Descent of Man," sixth paragraph of Ch. VIII.

Darwin thought of natural selection chiefly as the elimination of individuals by death.⁵ This is natural selection in the narrower sense. But it is better to avoid possible ambiguity by giving this kind of selection its distinctive name and separate treatment. It may appropriately be called lethal, that is death-bearing selection. Lethal selection, therefore, operates through the early elimination, or death, of relatively ill-adapted individuals. "Early" is here a relative term. Death operative by way of lethal selection occur either before physical maturity, or soon enough after to affect the amount of reproduction. Such death prevents the propagation of "unfit" characters.

Sexual selection depends on the advantage which certain individuals have over others of the same sex and species in respect of mating, and thus of reproduction.⁶ It is due to sexual preferences which favor the mating of certain individuals as against others of the same species, and so cause more reproduction of certain characters than of others; or, in another form, it is due to differences between individuals of the same species as regards power forcibly to appropriate mates. The first of these may well be called æsthetic, and the second combative, sexual selection. Failure to mate, not failure to survive, is the mode of elimination in sexual selection. The individual must become adapted to the phenomena of sex within the species, as well as to outside "nature." "Selection in relation to sex" has an important part in Darwin's theory of organic evolution.

Among animals it is the relatively passive sex which exercises choice in æsthetic sexual selection, that is, usually the female. Hence the beauty and song of birds are male attributes. In combative sexual selection, on the other hand, the competition takes the form chiefly of actual fighting between rival members of the active sex. There is a difference between this struggle for mates and the "struggle for existence." "Nature, red in tooth and claw" is poetic license. The phrase gives no true notion of the workings of natural selection. The poet is apparently licensed to be inaccurate. The struggle for existence is chiefly a noiseless, inglorious effort to wrest from the environment sufficient food to maintain life. For the rest, some animals prey and others are preyed upon. It is only in combative *sexual* selection, however, that bloody combat, which implies a degree of equality of prowess, is the regular thing. It is significant, likewise,

⁵ He says, for example, natural selection "produces its effects by the life or death at all ages of the more or less successful individuals." "Descent of Man," last paragraph of the section entitled The Male Generally More Modified than the Female, Ch. VIII.

⁶ These are Darwin's words, with the significant difference that he says "solely in respect of reproduction." See "Descent of Man," fourth paragraph of Ch. VIII. He thus fails to recognize what is called in this article reproductive selection, for his sexual selection is clearly a different thing.

that the comparison of nature to a cock-pit uses phenomena, not of natural, but of sexual, selection.

Reproductive selection depends directly on difference in degree of fertility. If any quality is generally associated with a particularly high or low degree of fertility, it is at an advantage or disadvantage due to this form of selection. Reproductive selection is the case of influences bearing directly on propagation, apart from obstacles to mating, in a way relatively to diminish or increase the number of offspring from individuals possessing certain characteristics. The idea of reproductive selection is not developed by Darwin,⁷ though it is fully in accord with his general theory and supported by his emphasis on propagation. It has little applicability to the lower animals, but for man it has very great importance.

Differences in ability to procure mates with resulting differences in number of offspring can be distinguished from differential results where the opportunity to mate and reproduce is equal. The former is sexual selection; the latter is reproductive selection. The two are related as pertaining to propagation exclusively, and are contrasted with lethal selection in that they do not involve the question of individual survival. Reproductive selection is a phenomenon of the diverse results of equal opportunities for sexual intercourse. Sexual selection is a matter of obstacles to mating, that is to getting opportunities for sexual intercourse at all. The former rests on differences between individuals as regards degree of reproductivity, granted mating. The latter turns on differences in degree of ability to obtain mates. Though an element of each form may be present in a particular case of selection, the distinction is important, especially in mankind.

In order that the individual shall be "selected" in the fullest sense, he must successfully run a threefold gauntlet. He must live to maturity and enjoy a long and vigorous prime. In obtaining a mate, or mates, he must be as successful as the "best" of his fellows. He must also, equally with the most favored of his species, possess and exercise the power to reproduce his kind and to hand down his characteristics to a numerous progeny. If he fails in the first particular, he is eliminated by lethal selection. If he fails at the second point, his kind is eliminated by sexual selection. If he fails in the third respect, his kind is eliminated by reproductive selection. In all these three particulars his failure need not be absolute, but may be a matter of degree, in which case the elimination is gradual. He may survive to maturity, but perhaps little beyond that. He may leave offspring that are too few in number as compared with those of his fellows. The critical question

⁷ The name and idea are contributions of Professor Karl Pearson. See his essay "Reproductive Selection" in his "Chances of Death and Other Studies in Evolution"; also "Contributions to the Mathematical Theory of Evolution," III., in the *Philosophical Transactions of the Royal Society*, Vol. 188, p. 253.

always is: Whose descendants are to represent the future of the species? The question is one. But a decision may be rendered at any of several different points.

The three forms of selection so far mentioned apply to individuals. Group selection is recognized by Darwin, though not treated separately, nor by him distinguished from natural selection. Group selection results where a number of individuals act and suffer jointly, whether with conscious purpose or not, in matters affecting their success and survival in competition with other groups.⁸ It is selection operating groupwise.

We have distinguished three forms of selection of individuals, over against which is now set group selection. It may appear that we should make a triple division of group selection, as we have of the selection of individuals. It is obvious, however, that the concept of sexual selection is entirely inapplicable. A group does not propagate its kind by a sexual relation with another group. Reproduction, of course asexual, might be predicated of a group. The idea of reproduction, however, as applied to the group, is but an analogy; and where so applied, it is of little or no significance for selection. Reproduction of its individuals is not reproduction of the group, for the group remains the same while its members change, just as does the body while its component cells die and are replaced by others. The group is thus potentially immortal and does not regularly reproduce itself. When a successful group becomes unduly large, it may divide or send out a "daughter colony," thus, so to speak, propagating itself by fission. But this is a question of size, not of differences in degree of natural reproductivity on the part of groups. As regards the "decease" of such a selectional group, moreover, it comes either by dissolution, that is, by the loosening of its bands and the dropping away of its members, or by their physical death. In the former case selection has not yet completed its work. In the latter case its work has taken an individual form. The ultimate incidence of group selection is always on individuals, affecting them either in the duration of their life or in their reproduction. But the effect is likely to be compound. From which of these two sorts of selection it comes, and how much is from one or the other form, are questions which have little importance from the point of view of the group. Therefore, if it is possible, it is not worth while, to attempt to subdivide group selection into lethal and reproductive forms.

Group selection is logically coordinate with all three of the other forms. In practise, however, taking account of its degree of importance, as well as of the fact that it is not to be subdivided, we may

⁸ In the choice of terms, I have preferred to name the kind of selection from its characteristic means at the decisive point. But I have not been able consistently to hold to this terminology in the case of group selection.

treat it as on the same level with lethal, sexual and reproductive selection, constituting a fourth species.

It is repeating to say that successful reproduction of kind is the essential fact in selection. But the importance of the point is great enough to bear such a repetition. It is significant that Darwin got his idea from the practise of breeders of domestic animals, which is based upon the principle of reproductive selection. Lethal selection is more radical and more incisive in its methods, but death itself operates as a selective agency only through preventing reproduction. Elimination by death after the reproductive period is passed is not selectional. It merely makes more room for the new generation. Lethal selection comes through *early* death. It is probable that most animals die either when very young and immature or else after considerable reproduction. Survivorship tables for man exhibit the same general phenomenon, that is low mortality at the prime of life. Though we can not know all the possibilities of selection until we distinguish the four modes, they are not independent explanatory principles. All are reducible to effective propagation of kind, to success in leaving offspring. The fate of the individual as such, counts for nothing. For selection, the continuation or destruction of the line of descent is *the* thing. An individual is important only as belonging to or representing such a line of descent. The "struggle for existence" is only an incident, or a method, in selection. Selective propagation is what is essential.

The classification above presented is made with reference to the needs and point of view of the sociologist. One might well doubt whether the careful discrimination of reproductive selection, which has been attempted, would be at all justified by the little scope of application it finds among the lower animals. We know that sexual selection also has but limited applicability, and only to higher forms of life. In strictness, reproductive selection has been the factor that has, on occasion, adaptively increased the fertility of a species, no matter how low in the scale: while natural selection must have been the means of adaptively decreasing such fertility. But this is a minor point. Sexual selection seems to be the nearest that nature comes to admitting reproductive selection as an important factor. As regards domestic animals, also, what the breeder controls is mating rather than strictly and directly reproduction. This case well illustrates the difficulty of sharply discriminating reproductive selection. In man, however, fertility is extremely variable, by nature and through artificial means, so that we must, in man, take account of sheer natality, apart from other selective factors.⁹ It is significant that the point of view of

⁹ Perhaps it might be better, for this reason, to use the term "natal selection" for what has been called "reproductive selection," and reserve the latter for general use to cover both sexual and natal forms. But the term "natal" suggests germinal selection, and the idea of selection at birth or soon after would also be brought to mind, which is of course lethal selection.

the sociologist is, in the matter of selection, more inclusive, and more exhaustive of selective possibilities, than that of the biologist.

In our fourfold classification we have left out the term "natural selection." For its narrower, specific meaning "lethal selection" is decidedly preferable. Might not the older phrase be used as the generic name for all the forms of selection? Usage seems to favor this. "Selection," without a qualifying adjective, is logically the generic term, but is not yet so established as to be unquestionable. Natural selection is therefore convenient as a make-shift or substitute general term. It is familiar, and all the forms of selection do occur in nature. So, despite the implication of Darwin's practise in relation to sexual selection, natural selection might be used roughly for all four classes, though with a saving clause against including such a thing as purposive breeder's selection.

SELECTION APPLIED TO MAN

In the attempt to apply selection to man, clearness of conception has often been lost. Two sorts of mistakes have been made. The complexity of life in civilized society, as compared with the simplicity of nature's conditions, has invited, on the one hand, to extensions of meaning, by which processes have been described as natural selection which are not selection at all. In particular, it has been supposed that segregation by economic or social success is selection. It is rather selective dissociation. This is an important preliminary to selection, but the incidence of the latter may as well be unfavorable as favorable to the survival of those who rise in the social scale.

There are, on the other hand, sociologists who deny that natural selection, meaning by that lethal selection, is of much significance for man. Such are likely to develop and emphasize contrasts between natural selection and what they chose to call "social selection." This is a conception for which the writer finds little use. Social selection should mean selection *by* society, and since society, unlike "nature," is to some degree conscious and purposive, social selection should mean more or less conscious selection by society. Whatever selection there is of this sort may still be brought under one of our four forms. But there are more, and more important, non-teleological sorts of selection resulting from characteristically social processes. And such phenomena of selection *in* society are what those who talk of social selection have chiefly in mind. These are provided for in our classification, though in distinguishing types use has been made rather of the method of the selection. To attempt to distinguish forms of selection according to the varieties of selective conditions would give an almost endless list, and the differences would not be of explanatory or scientific importance. We may speak of military or religious or industrial selection if we will, but these are descriptive terms rather than logical categories. This fact has not been perceived by those sociologists who,

rightly departing from the rough and ready practise which calls almost anything natural selection, have wrongly gone on to find about as many different forms of selection as there are social institutions and customs.¹⁰

As regards the scope of selection in general in its application to man, we are now prepared to believe that any influence that bears in any of the four ways enumerated upon the continuance of lines of descent presumably has selective importance. Only on the hypothesis of pure chance distribution of effects can any influence known to affect propagation be declared to be non-selective. The chances against this are infinity to one. No enumeration can cover all possible selective agencies. Every habit, custom and institution of man might well be examined with a view to detecting such effects. Selection must have tremendous importance in human society. It certainly is a central problem, perhaps the fundamental problem and point of departure, for a science of society.

Only the confounding of selection in general with mere lethal selection can explain the opinion that selection is inoperative in human society. Even so, the opinion is not well-considered, for there is much selection by death in civilized man. Lethal selection is not a matter of violent death, or death in struggle. The conception of natural selection as the result of a "free fight"—a *bellum omnium contra omnes*—has no justification in any phase of its application. Half the population of many civilized societies, and of course on the whole the weaker half, dies before reaching maturity. In the parts of the United States for which tolerable registration statistics are to be had, at least one third of the deaths are of persons under the age of fifteen. This involves lethal selection.

But lethal selection is not all. The forms and agencies of selection multiply as we pass upwards in the organic series. Hence we might expect a culmination, as regards manifoldness and complexity, in man. It is true that there are fewer births to select from, but the selection may come before birth, and in fact comes so always in the last analysis. And if there is less selection by death in man, there is also less random and indiscriminate destruction of human than of lower animal or plant life. The field for the study of selection in human society is as great and as complex as that in which the biologist works.

Of lethal selection in its application to man, little more need be said. Life-tables and deaths according to age tell the story. Lethal selection is not to be dismissed with the statement that men no longer habitually attack and kill one another, and in civilized states do not die for want of food. Of course selection by the dissolution of the weaker constitutions relates chiefly to physical qualities, but its im-

¹⁰ Lapouge, in his "Les Selections Sociales," perhaps best illustrates this tendency.

portance for that is great indeed. Modern improvements in medicine and surgery may check the incisiveness of such action of selection. But they can only lower, not destroy, the standard set for survival. Lethal selection, however, even as regards mere physical qualities, amounts to much less for Occidental civilized man than for any other species of living thing. But some other species of selection are proportionately more important.

A weightier consideration that might appear to make lethal selection of less interest to the sociologist is the fact that it appears hardly to touch what is distinctively human in man's constitution, that is, his mental and moral qualities. But such selection does in fact promote mental stability, so far as the strain and stress of modern life drive men to insanity and death. Alcoholism, too, as is proved by the experience of life insurance companies, and by statistics of occupational mortality, tends to eliminate those who are in this respect deficient in self-control. In various ways the ignorant, the imprudent, and the vicious, tend to destroy themselves.

The effects of sexual selection are much more deeply marked in the organisms of birds than among mammals. The sexes in civilized man, however, show pretty clearly its differentiating influence. The greater strength of the male in man is probably due in part to sexual rivalry. As regards women, on the other hand, their conventional title, the "fair sex," is probably due to something more than mere chivalry or mere flattery. The pretty girl still marries better or earlier than her less "well-favored" sister. It is to be hoped that more important qualities than personal appearance are also favored by sexual selection.

Alfred Russel Wallace, the co-discoverer with Darwin of natural selection, though he curiously enough grudges recognition of it as a factor in the evolution of lower animals, apparently because it involves rather highly developed mentality, sees in esthetic sexual selection on the part of women the great means to the future progress of the human species.¹¹ With this opinion, the writer can not agree. Marriage is not so much a result of exclusive and exacting "elective affinities" that the relatively ineligible can not solace themselves with those of the other sex who are similarly situated. The approximate equality of sex numbers and the institution of monogamy, which forestalls monopolizing tendencies, leave no considerable class of persons eliminated by lack of opportunity to marry. Postponement of marriage on this account is probably of some influence, but of no great importance. Postponement of marriage and abstinence from it—the latter amounting to more than one fifth in some regions—are probably due to variation in the relative strength of the marital and repro-

¹¹ See his article, "Human Selection," in the *Fortnightly Review*, Vol. 54; also *POPULAR SCIENCE MONTHLY*, Vol. 38.

ductive tendency more often than to failure to find opportunity to marry. Sexual selection is probably still of some importance in man, though of problematic influence.

Reproductive selection is by far the most important of selective instrumentalities operating in civilized man. Here, and very recently, it has first come to great importance. One sixth and more of marriages in certain portions of civilized society are infertile. And differences in the number of children to a family are still more significant. This absolute or relative infertility must be more or less selective in its incidence. Nerve-racking indulgences and ambitions suggested or elicited by civilized life seem to create physiological conditions unfavorable to reproduction. Still more important is the fact that, with the increase and spread of physiological knowledge, the size of the family is placed under the control of volition, and children are no longer a necessary or to be expected result of sexual gratification. So the wish not to be bothered with children, with the moral traits it implies, leads to elimination. Over-cautiousness and desire to pamper children, on the other hand, resulting in the so-called "two-child system," bring about, though more slowly, the same result. The over-cautious in such matters certainly will not "inherit the earth." Conscientiousness on account of transmitting physical weaknesses acts in the same way. Celibacy as a religious observance has probably taken from society some of its gentlest natures.¹²

An average of nearly four children to a family is necessary to keep up the numbers of a population. For a family to have fewer is likely to mean that it will have less representation in the next generation than in the present. Such a family is certainly not holding its own in a country of increasing population like the United States. Hence the plaint of "race suicide," which is in fact never *race* suicide, but only the self-elimination of a particular section of society. The blood of France may become Breton, but it not at all likely that France will lose its population. The New England stock, which populated the West, is probably now declining in numbers in its old home by deficiency of natural increase.¹³ But New England is gaining population. There are always relatively and absolutely fertile elements in society, as well as the relatively infertile. The significant thing is what are their differences as regards mental and moral traits. Is "race suicide" due more to selfishness or to over-caution? Is high fertility due more to improvidence or to the love of children? How far is a high standard of life associated with the most desirable mental traits?

¹² Galton notices this selectional influence as early as 1869, in his "Hereditary Genius," though of course without distinguishing it as reproductive selection.

¹³ See articles of R. R. Kuczynski in the *Quarterly Journal of Economics*, Vol. XVI.

Clearly reproductive selection is the most important selective influence in present social evolution.

Men act and suffer jointly. Man is a social animal, and he is such through adaptation. Primitive man, like many lower animals, associates himself with others for mutual protection and support. Hence the strength of tribal attachment and of clannishness. To group selection chiefly is to be attributed capacity for cooperation and those feelings of regard for others on which morality is based. The attachment of mother and child is primeval and of course strongest. But the family, created by the presence of the father, is the earliest persistent, truly social group. Still more characteristically social is the bond of union between grown-up brothers and sisters. Out of kinship grouping has grown the broader, though vaguer and less intense, recognition of fellowship contained in morality. Morality has been called the egoism of the group. When developed and refined, it is much more than that, but it is based upon the instinct that draws men together.

Group selection is probably at its best in primitive man. Bagehot's classic discussion of the evolution of a coercive social organization is an application of group selection. But in modern occidental society the process of individualistic atomization has been carried so far as to threaten the disintegration even of the family. Large family, clan, tribe and village community are gone. There is left little but the individual, or the natural family, and the state. What "groups" there are between the state and the family are largely mere expressions of an appetite for association which finds no other and more important object upon which to exercise itself. And the state is of no importance for group selection. It has become a thing of contrivance and a matter of social psychology. The family is the only group left that is of much selectional importance. Of progressive national states there are too few, in the face of the many questions to be answered, to offer the necessary material. And they interpenetrate by migration in a way to defeat selection groupwise.

Selective dissociation is so closely related to selection, and so often confounded with it, that it requires mention here. There is selective dissociation where individuals of more or less similar traits are segregated from others and put into a special environment of a nature to affect their survival.¹⁴ The incidence of the forms of selection varies with geographical region and social class. The process of dissociation is not directly selection, but only indirectly important as its preliminary.

Economic and social rise has been mentioned as often confused with "survival." Survival it is not, but merely selective dissociation

¹⁴ The term "dissociation" is used by C. C. Closson in articles in the *Quarterly Journal of Economics*, Vols. X. and XI.

of those possessing traits making for success. It probably means selectional disadvantage, owing to the heavy incidence of reproductive selection on "successful" families.

International migration to a new country is another case of selective dissociation. The American colonists were undoubtedly, on the whole, men of superior initiative and independence of character. Their coming to America made possible the multiplication of their descendants and their kind. Even our present-day immigrants are rather superior in point of energy to those of the same economic condition who remain behind, and they come to an environment presenting greater opportunities.

Urban migration is a notable example of selective dissociation. According to the indications of anthropological and other evidence, it is the more energetic element that migrates from country to city. Under conditions prevailing down into the nineteenth century, cities could not maintain their population by natural increase. Migration to the city then meant subjection to an unusually severe incidence of lethal selection. Our modern sanitary improvements have not yet entirely removed the disadvantage of the city as compared with the country.

We have mentioned selection *by* society as possible, but not a very important fact. The execution of criminals and their imprisonment, so far as it prevents reproduction, are cases of such selection. In crueller ages, with numerous capital crimes and many executions a year, this may have been an important mode of selection. Now it amounts to little. Perhaps public opinion, also, puts certain members of society under some selective disadvantage.

Francis Galton has proposed that society deliberately undertake the improvement of the human stock.¹⁵ He would have certificates of fitness issued and suggests the giving of marriage portions to girls of superior personal qualities and good family. Such a program of "eugenics" would operate through reproductive selection. It is an interesting proposition, if not very practical. Hitherto the method of evolution has been essentially negative, that is, primarily the elimination of the unfit. Will any human society ever be wise enough positively to map out the line which further evolution shall take? The definition of what is *undesirable* is much simpler than the definition of what is *most* desirable.

In the above brief review of the incidence of selection in man, it has been the intention of the writer merely to give examples illustrative and suggestive of the applicability and importance of the dif-

¹⁵ POPULAR SCIENCE MONTHLY, Vol. 60, article at page 218. He has also brought up the subject before the British Sociological Society. Reports of the discussion are printed in recent volumes of the *American Journal of Sociology*, as well as in the society's Sociological Papers.

ferent forms of selection for the study of man and his social evolution. An extended treatment of this subject is one of the great desiderata of the science of sociology, the half of which will be the theory of selection in its application to man.

A logical and seemingly very forcible objection to the idea that selection applies to man is contained in the contention that heredity has nothing to do with the higher, which are the distinctively human, qualities in human nature. But the common-sense and practical view is that even the highest intellectual and moral qualities are to some extent inheritable. Men look for family traits not merely in the physical features of children. There is certainly a tendency to the inheritance of insanity, which shows that mind is subject to heredity. It is enough for the purposes of the sociologist if the inheritance of the properly human qualities be only statistically true, that is, true for the mass, though not true of every individual. In fact, this is what we should expect. For a number of reasons variation should be at its best in characteristics distinctively human. Biologically viewed, man is like a domestic animal and is a dominant species, both of which facts imply great variability. There is also approximately unrestricted crossing in mankind. The environment, that is complex civilized society, demands diverse specialized qualities; so that the external conditions favor multilinear evolution. The distinctively human qualities have been latest acquired and are therefore most subject to variation. In man, moreover, as the most socialized of animals, much may be left to imitation and education, that is, to "social heredity." Hence there is less need of a hard and fast physical heredity.

The fact that the line of least resistance in development is the resultant of two sets of forces, internal (variation and heredity) and environmental (selection), must not be allowed for an instant to slip the mind. The interdependence and delicacy of adjustment between these forces increases with the complexity of man's higher, special characteristics. Hence the apparent decrease in the importance of heredity. The distinction between what is innate and what is acquired often hinges on mere ease of enumeration of cases of apparent predominance, or relative independence, of one or the other factor. Or the results are referred to the least easily assumed to be constant factor. Such is in practise man's application of causation. Both sorts of factors are always necessarily operative. It must be granted that proper inheritance is a necessary precondition to the appearance of noble qualities, and this alone concedes the presence and importance of heredity. Both internal constitution and modifications from without are determinants of development and man can no more get along without the right sort of heredity now than ever. Complexity and lack of fixity in development do not remove from the sphere of heredity, though they do mean greater possibilities and greater likelihood

of variation. They do also give opportunity for the development of a new set of factors in evolution, the socio-psychical. It can not be too strongly emphasized, however, that these socio-psychic factors are conditioned by their foundation in the innate qualities and capacities of human nature, that is, in the characters given to men by selection.

It may be that the power of heredity is limited short of the powers of evolution and development. But this does not seem to be true for the higher moral qualities, nor for conspicuous intellectual power, though it is perhaps well to add the caution that heredity appears to be not yet thoroughly established for these qualities. But selection itself can make heredity more stable. It would be enough for the most utopian sociologist if all human beings could be brought up and kept up, by the fixation of heredity, to the present highest level of intellectual power and moral character. So much progress selection may accomplish. Whether it does, depends on the adaptation of human institutions to such remote ends.

The question as to the applicability of natural selection to man can not be satisfactorily dealt with as one simple whole. Here as elsewhere analysis is the necessary instrument of science. By analysis we discover four distinct modes of selection: lethal, sexual, reproductive and group selection. We find, also, that these four forms have very different sorts of applicability in the explanation of man's evolution, past and present. Especially under present conditions it is reproductive selection that most calls for consideration.

In these days "race suicide" is a much talked of subject. There is plenty of occasion for the discussion. But the fact that attracts attention is not rightly called race suicide. Literally interpreted, race suicide is an absurdity. The actual fact that is attracting attention is a phase of reproductive selection. Its importance can hardly be exaggerated. But it can be truly evaluated only as seen in its setting as a phase of a form of selection. The fear of race suicide as a matter of *quantity* of population is no more valid or justifiable—it is rather far less justifiable—than the contrary and equally unanalytic fear of over-population awakened in Malthus and his followers a century ago. The question is not so much one of *quantity*, either by excess or deficiency, as of *quality* of reproduction and of population. It is therefore a question of selection. In this matter of selection in mankind it is doubtless true that "race suicide"—if the term means the self-elimination of certain classes of members of society—now plays the most significant part.

ILLUSTRATIONS OF MEDIEVAL EARTH-SCIENCE

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C'est vers le Moyen Age énorme et délicat,
 Qu'il faudrait que mon cœur en panne naviguât.

—PAUL VERLAINE.

MODERN experimental science dates only from the sixteenth century. The habit of interrogating nature, the application throughout all departments of research of the observational and inductive methods, the thirst for fresh discovery and invention, and the irrepressible curiosity that inquires into the innermost recesses of the wonderful world we live in, seeking to ascertain its laws and acquire mastery over its forces—all these leading characteristics of modern science were absent from its medieval prototype.

In reality, the so-called science of the middle ages is scarcely worthy of the name. Infinitely inferior as compared with modern science, it was still more crude, more distorted, more fantastic and illusory than that of ancient times. Medieval man had no clear-eyed perception of the visible world, actuality possessed for him little value, that which really is and happens was without special significance in his eyes. What the medieval man saw he interpreted as a symbol, what he heard he understood as an allegory. Dante himself is our best witness that cultivated men of his age esteemed the speculative life vastly superior to the practical.

Under the conditions of hopeless barbarism that existed from the seventh to the eleventh century there could be no real culture, and intellectual activity continued at an extremely low ebb. Religion absorbed almost all other occupations of the mind, faith was exalted as a sovereign virtue, mere empirical knowledge was disdained and rejected. As the Christian religion became the leading subject of men's thought and interest, so the principal business of their lives throughout the middle ages was the salvation of their souls. External conditions were unpropitious, subjective conditions inhibitory for the development of scientific ideas. Hence it was inevitable that learning should become decadent, and the proud record of ancient achievement forgotten. Indeed, as early as the fourth century of our era, before all relics of the old culture had disappeared, Eusebius wrote:

It is not ignorance which makes us think lightly of science in general, but contempt for its useless labor, while we turn our souls to better things.

Two centuries later Pope Gregory the Great protested against the study of pagan literature,

because the praise of Christ and the praise of Jove are not compatible in one mouth.

Again in the tenth century, a period of utter stagnation, illumined by scarcely a ray from classical antiquity, church dignitaries maintained that

the successors of St. Peter wish for their teachers neither Plato nor Virgil, nor Terence, nor any other of the philosophic cattle.

But with the revival of learning during the next two hundred years came a change for the better, and medieval knowledge began to assume a more positive character. Its science, still contaminated with the errors and superstitions it had received from remote ages, gradually became less chaotic, less fantastic and symbolic, less dominated by theology, although for a long time after its subjection to scholastic influences it remained, so to speak, Aristotelized. That is to say, logical analysis was relied upon for ascertaining all manner of truth, a complete system being devised toward that end by Raymond Lull. The independent searching out and testing of actual facts, the process of drawing general conclusions from concrete phenomena, were not the methods employed by medieval schoolmen, with the one notable exception of Roger Bacon.¹ It was commonly held that all truth may be obtained by the use of reasoning alone; and "that by analyzing and combining the notions which common language brings before us, we may learn all that we can know. Thus logic came to include the whole of science." (Whewell.)

There can be no doubt that the universal reverence for Aristotle's authority, and blind acceptance of other accredited doctrines and treatises, greatly retarded scientific progress. All men begin their development with a childlike trust in authorities and examples, and as science had to be regenerated *de novo* toward the end of the middle ages, it is only natural that its beginnings should appear to us lamentably weak and puerile. Moreover, the system of instruction employed by Catholic schoolmen was not conducive to real enlightenment. The real difficulty, as has been pointed out, is that "not life and nature were the basis of instruction and science, but books. Not the thing itself was the object of inquiry, but the word; not experiment disclosed the truth, but dialectics." Authority had greater weight than arguments, and in the last resort authority depended more upon a master's reputation than on his knowledge. Finally, we must not forget the restraint imposed upon medieval philosophy by theology. Religious discipline required that the results of human reason should be con-

¹ On Baconian contributions to science, see Professor Holden's interesting article in *POPULAR SCIENCE MONTHLY* for January, 1902 (60: 255).

formable to church dogmas, and woe to him who dared insinuate that whatever was taught by the church was not also the logical outcome of human reasoning.

Thus, freedom of the intellect had to contend not only with formidable difficulties imposed from without, but with no less effective hindrances, wrong conceptions and limitations that came from within. While these conditions lasted the net result was sterility. In time, however, that innate longing to escape the bonds of ignorance, that patient and zealous striving after truth which stimulates all lofty endeavor, these impulses gradually became more assertive; and, triumphant at last, gave rise to our modern critical science.

It would be impossible to attempt here even a superficial sketch of the remarkable rise and expansion of empirical knowledge that took place during the twelfth and thirteenth centuries, by virtue of which Dante's era merits its appellation of *secolo d'oro*. The innumerable commentaries that have been devoted to the most striking figure of the middle ages attest the difficulty of preparing an adequate survey of contemporary knowledge. Remember, too, that the peerless poet stands out from the midst of a notable company of erudite laymen and clerical scholars. It will be sufficient to recall only such names as those of Ser Brunetto Latini, whom Dante expressly calls his 'master,' and whose encyclopedic work embraces practically all the science of his time; Albertus Magnus, often styled the "Universal Doctor," and his famous disciple, St. Thomas Aquinas; those brilliant Anglican geniuses. Roger Bacon and William of Ockham, forerunners of the modern spirit of investigation; and those twain Italian luminaries whose souls were fired with the glow of ancient and of the newly revived culture, Petrarch and Boccaccio. Still earlier, and entirely independent of Christian influences, the Arabian circle of sciences had gained new luster from Averroës, its chief exponent and adornment.

But besides these greater lights there shone many of feebler intensity, yet none the less worthy of grateful esteem, since their combined rays helped toward clearness of vision. There was one erudite scholar, for instance, who was formerly rated as a mere imitator and plagiarist of Albert of Bollstädt; whereas we now know that the reverse was true, in that the master drew largely upon his disciple for materials in preparing his huge compendium on natural history. This was Thomas of Cantimpré, who wrote during the third and fourth decades of the thirteenth century, and whose works were widely read and translated. His chief contribution to science was a treatise entitled "De naturis rerum," which served at once for the source and model of Conrad of Megenburg's "Buch der Natur," the earliest of its kind to be written in the German vernacular.²

Conrad, however, considerably amplified the work of his Brabant

predecessor, and is further interesting to us for displaying power of original observation. He had also the happy faculty of meditating upon his observations, and was by no means averse to offering his own explanation of the causes of various phenomena. Accordingly, it has seemed worth while to reproduce a passage from this author relating



ALBERTUS MAGNUS.

to earthquakes, for the reason that it offers a very fair presentment of the status of geological speculation among medieval schoolmen. The second illustration has been selected with similar intent from the "Cosmography" of Ristoro of Arezzo, written in 1282. Dante's acquaintance with Ristoro's work has not been definitely proved, but is regarded by competent authorities as highly probable.

² A modern German edition of the text was published by H. Schulz in 1897. The most recent study of Thomas Cantimpranus is by a Dutch author, Dr. W. A. Van der Vet, entitled "Het Bienboëc van Thomas van Cantimpré," 1902.

ON THE NATURE AND CAUSES OF EARTHQUAKES

(Extract from Conrad of Megenburg's "Buch der Natur," 1359)

The fourth and nethermost element is the sphere of earth. Its distance from the firmament [of the fixed stars], as determined by divers scientific men, both pagan and Christian, is 309,375 miles. No one can impugn the accuracy of this result, depending as it does upon laborious calculation and the reduction of very delicate astronomical observations. None but unlettered folk contemn such investigations. Ignorant persons are unable to comprehend that a geometer may station himself outside the town and accurately determine the height of turrets within the town by means of angular measurement. Yet in sooth is it possible. By a similar method we ascertain the distance from earth to the starry heavens.

The earth is the only one of the four elements that is favorably adapted for man; it is peculiarly his province, as heaven is the habitation of God and the angels. The earth element alone is innocuous to man, the others often injure him. For water drowns, foul air suffocates, and fire consumes him. The earth is by nature cold and dry, externally harsh, yet concealing within its bosom full many beauteous things, such as precious stones and the noble metals. By a like token, many an humble citizen may possess jewels within his heart. The earth-realm is very luxuriant, and the only one that brings forth fruit in abundance. How many miles it measures in circumference, and the extent of its diameter, I have already set forth in another place,³ and likewise have explained the cause thereof, why it does not fall away from its abode in space. As the heart is lodged within the mid-portion of the body, so is hell seated at the center of the earth. Thus do our reverend masters instruct us.⁴

Of it happens that the earth trembles, causing cities to fall, and mountains to crash together. Simple folk know not the reason of this, but foolishly believe that the earth is borne up by a mighty fish, which carries his tail in his mouth; and the turning or moving about of this creature causes the earth to shake. But this is a myth.⁵ Remains for

³ Conrad's data as to the dimensions of the earth and its distance from the several heavens are possibly derived from the same source as Dante's and Brunetto Latini's, namely, the *Elementa Astronomica* of Alfraganus, cap. xxi. Roger Bacon's calculation of the earth's circumference was only one-fourteenth smaller than the truth, and Ristoro's independent reckoning of the latitude of Arezzo, in 1282, was in error to the extent of little more than one degree.

⁴ S. Thomas Aquinas teaches with regard to hell that it is probably situated under the earth and that its fire is of the same kind as terrestrial fire, an *ignis corporeus*. (*Summa theol.*, Suppl., Pars iii., Qu. 97.)

⁵ Probably an echo of ancient Titan myths, though having affinity also with the Arabian voyages of Sinbad. The existence of a great sea-monster was a very popular legend in the middle ages, the creature being sometimes identified

us to give true relation of this marvel, and to explain the cause of its occurrence. Now earthquakes originate in this manner, that within subterranean cavities, and especially in the interior recesses of mountains, vapors are compacted together in such vast quantities, and under such tremendous pressure, as to exceed at times all means for restraining them. They crowd in all directions against the walls of the interior caverns, fly from one to another of them, and continue to augment in volume until they have surcharged an entire mountain. The increase of these vapors is occasioned by the stars, especially by Mars and Jupiter. When now the vapors are confined for a long period within the subterranean cavities, their pressure becomes so prodigious that they burst forth with enormous violence and rend mountains asunder. Even when they fail to break completely through the crust they are yet able to produce a severe shock.

There are two kinds of earthquakes. Those of the first sort cause a gentle swaying of the ground like the rolling of a ship at sea. This movement is least destructive of fortresses and houses. The reason for this is that the vapors upheave the crust in a single supreme effort, and thereupon relapse in energy. Disturbances of the second sort are those which produce tremblings of the crust by means of a succession of sudden shocks, the motion being comparable to that of hand-shaking. Their effect upon buildings is most disastrous, solid masonry being shattered and hurled down by them. The process involved in this class of earthquakes is that one vapor rushes in pursuit of another, and drives it violently from side to side.

That the causes are verily as we have described is supported by abundant evidence. First, when a catastrophe is about to happen, premonitory rumblings are heard that resemble nothing so much as the noise of an hundred thousand hissing serpents, stridulating in chorus; or again there may be bellowings like unto those of maddened bulls. These sounds proceed from the violent agitation of the vapors within the interior of the earth, forcing their way through crevices and struggling to become liberated. Secondly, the sun shines feebly, or appears reddish-hued by day, owing to the heavy pall of smoke that rises from the earth's surface and obscures the view. Thirdly, it is well known that immediately after an earthquake the air becomes virulent, so

as Cetus (the whale), or the Craken of the north, or again merely as a gigantic fish. In the bestiary of Philippe de Thaun the incident is given in a few lines beginning:

“Cetus ceo est mult grant beste, tut tens en mer converse,
Le sablun de mer prent, sur son dos l'estent.”

The monster reappears under the name of Jascom or Jasconius in the old Celtic legend of St. Brandan:

“Jascom he is i-cleped, and fondeth nite and dai
To putte his tail in his mouth, ac for gretnisse he ne mai.”

that many people die. The reason for this is that when the vapors have been confined for a long time underground they become fetid and noxious. The same thing happens in wells that have long remained foul and choked up, for when these are again opened for cleansing purposes, the first workmen to descend into them are often asphyxiated.

Many wondrous effects are wrought by earthquakes. Note first that the vapors escaping at such times frequently transform men and beasts into stone, especially into rock-salt, and this is very liable to happen in mountainous regions or in the vicinity of salt-mines. This lapidifying property of the vapors is due to their enormous condensation. So affirm the eminent doctors of science. And I myself have heard it reported that high up in the Alps as many as fifty neatherds with their beeves were turned to stone in this manner; with them also was a dairymaid engaged in drawing milk, and transfixed in that attitude at the selfsame moment when all were petrified. Note secondly that earthquakes are often accompanied by flames and glowing ashes which shoot up from below and ignite houses, villages and towns. Yet a third accompaniment of earthquakes is the belching up from below of vast quantities of sand and dust, sufficient to engulf whole cities.

CONCERNING THE PROCESSES OF MOUNTAIN FORMATION

(From Book VI., Chapter 8, of Ristoro d'Arezzo's "Composizione del Mondo," 1282)

And we have ourselves discovered and excavated near the summit of an exceedingly high mountain remains of numerous species of fish and other creatures, such as various members of the shark tribe, and even shells that had retained traces of their original coloration. And in the same locality are found also different varieties of sand, gravel, water-worn pebbles and boulders scattered about in great profusion, apparently deposited by aqueous agency: and this we consider proof that the mountain in question was formed by the flood.

And we have at another time ascended a lofty mountain whose summit was composed of a thick stratum of very hard rock, of ferruginous color, and whose structure was as clearly the work of design as a vase is evidence of the potter's art. A huge castle, almost a citadel in fact, rested upon cliffs of this formation, and all the strata out-cropping at that altitude reposed upon other beds that had plainly been formed by water action. And the proof thereof consists in this, namely, that as one examines the strata exposed along the flanks of the mountain, one finds in certain places earth commingled with sand, at others tufa along with stones rounded by water action, and again elsewhere, quantities of fish remains belonging to various species, and also numerous other beds of divers kinds; all of which proves that this particular mountain, and the others already mentioned, near

whose summits occur fish remains, were formed by the deluge. Yet this same catastrophe may very readily have formed other mountains which do not contain sand and fish remains, the difference being occasioned by the nature of sediments existing in particular localities. Such, then, is the process of mountain-making. And the reason why mountain chains must have been formerly sea-bottom, or deposited in marine basins [before their upheaval], is that the volume of fossiliferous and arenaceous sediments is far too considerable to be ascribed to the agency of rivers, or of any other body of water inferior to the sea itself. . . .

[The continuation of this passage is devoted to seismic and volcanic phenomena, which are discussed more particularly in a subsequent section (Distinzione vii. parte iv.). The author expresses himself upon these questions, as well as upon the meaning of fossils, erosive action of water in molding land surfaces, scintillation of the stars, etc., in eminently scientific manner. His elder contemporaries, Albertus Magnus and Vincent of Beauvais, also note the existence and teaching of fossil remains. Similar inferences are drawn by Cecco d'Ascoli, the ill-fated author of *l'Acerva* and envious rival of Dante in the latter part of the thirteenth and first quarter of the fourteenth century.]

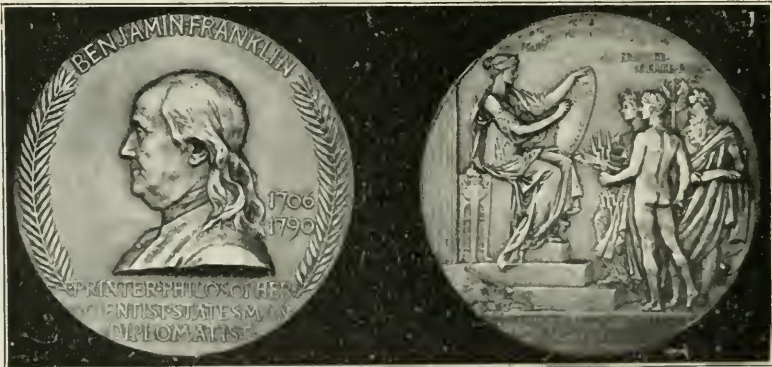
THE PROGRESS OF SCIENCE

*BENJAMIN FRANKLIN AND THE
AMERICAN PHILOSOPHICAL
SOCIETY*

THE celebration of the two-hundredth anniversary of the birth of Franklin, held at Philadelphia last year under the auspices of the American Philosophical Society, has now been completed by the publication of a volume containing a full account of the proceedings. These proceedings were unusually impressive. The Pennsylvania legislature made an appropriation of \$20,000, and all the arrangements were carried out with admirable skill by the officers of the society. The commemorative addresses by Dr. H. H. Furness, President Chas. W. Eliot and the Hon. Joseph H. Choate are models of thought and expression. A special session was held to honor Franklin's researches in electricity, when addresses were made by Professor E. L. Nichols and Professor Ernest Rutherford. It is not necessary to repeat here all the features of the program, but attention may be called to circumstances which give opportunity to reproduce from the volume two interesting portraits of Franklin.

At the instance of the committee of the society, the congress passed an act enabling the secretary of state to have struck a medal to commemorate the two-hundredth anniversary of the birth of Franklin, one single impression in gold to be presented to the Republic of France and one hundred and fifty copies in bronze to be distributed by the president of the United States and the American Philosophical Society. The medal, designed by Louis and Augustus St. Gaudens, has under the face of Franklin the words "printer, philosopher, scientist, statesman, diplomatist," while on the reverse history writes in the presence of Literature, Science and Philosophy. This medal was presented by the secretary of state, the Hon. Elihu Root, and accepted by his excellency the French Ambassador, M. Jusserand.

The occasion of the Franklin bicentenary was taken by Lord Grey to present to the United States a portrait of Franklin painted in London in 1759 by Benjamin Wilson. This portrait hung in Franklin's house in Philadelphia, whence it was taken by Major André and given by him to the great grand-



THE FRANKLIN MEDAL.



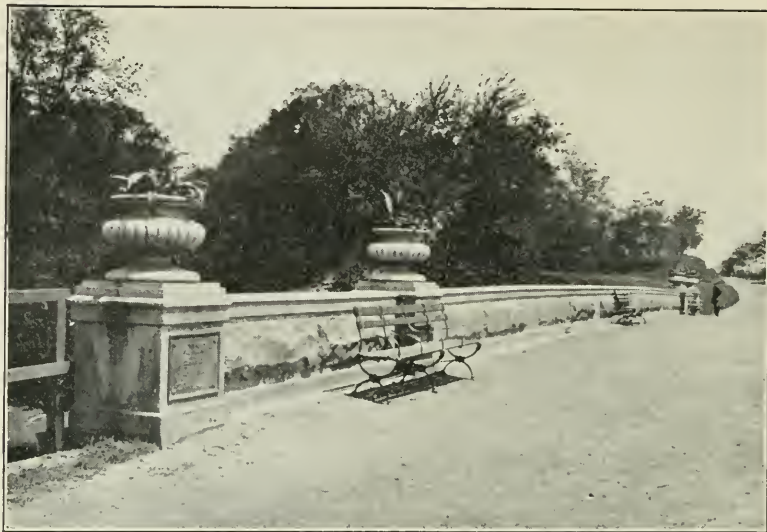
PORTRAIT OF FRANKLIN PAINTED BY BENJAMIN WILSON IN 1759.

father of Lord Grey. In the letter, read by the Hon. Joseph Choate, when the portrait was first shown after its return to this country, Lord Grey says:

In a letter from Franklin, written from Philadelphia, October 23, 1788, to Madame Lavoisier, he says: "Our English Enemies, when they were in possession of this city and my home,

made a prisoner of my portrait and carried it off with them."

As your English friend, I desire to give my prisoner, after the lapse of 130 years, his liberty, and shall be obliged if you will name the officer into whose custody you wish me to deliver him. If agreeable to you, I should be much pleased if he should find a final resting place in The White House, but I leave this to your judgment.



BRIDGE OVER THE BRONX RIVER, BETWEEN THE NEW YORK BOTANICAL GARDEN AND THE NEW YORK GEOLOGICAL PARK, DEDICATED TO THE MEMORY OF LINNÆUS

THE CELEBRATION OF THE BICENTENARY OF THE BIRTH OF LINNÆUS BY THE NEW YORK ACADEMY OF SCIENCES

THE two-hundredth anniversary of the birth of Carolus Linnæus has been celebrated throughout the world, notably by the Royal University of Upsala, where he was professor from 1741 to his death in 1774, and the Royal Swedish Academy of Sciences, of which he was the first president. Of the many local celebrations, we may select for mention that under the auspices of the New York Academy of Sciences, where the arrangements were more elaborate than elsewhere in America. The morning of May 23 was devoted to exercises in the American Museum of Natural History, the afternoon to exercises at the New York Botanical Garden and the New York Zoological Park, the evening to exercises in the Brooklyn Institute of Arts and Sciences and the New York Aquarium. At these different scientific institutions addresses were made by Dr. J. A. Allen, Dr. P. A. Rydberg,

Mr. F. A. Lucas and others. The building of the New York Aquarium commemorated the centennial of its erection, and the collections were opened for the first time by night.

Of special interest was the dedication to the memory of Linnæus of a bridge over the Bronx River on Pelham Parkway between the New York Botanical Garden and the New York Zoological Park. The bronze tablet, presented by Dr. N. L. Britton for the New York Academy of Sciences, bears these words:

Linnæus, botanist and zoologist, born Rasmalt, Sweden, May 23, 1707; died Hammarby, Sweden, February 18, 1778. This bridge was dedicated by the New York Academy of Sciences, May 23, 1907.

A cable message addressed to the New York Academy of Sciences by the Swedish Academy reads as follows:

To every Swede, and especially to our society, whose honor it is to count Carl von Linné as the greatest ornament of its ranks, it is highly gratifying to see that the memory of the man whom all the world recognizes as Princeps Botanicorum is also held so sacred across the Atlantic that the two hundredth anniversary of his birth will be celebrated there with the same love and reverence as in his own country. And we fully appreciate the delicate courtesy which has led you to immor-

talize his name among you by dedicating to him the beautiful bridge which unites your Botanical Garden with the Zoological Park.

THE STATE UNIVERSITIES AND
THE SYSTEM OF RETIRING
ALLOWANCES OF THE
CARNEGIE FOUNDATION

IN Mr. Carnegie's original letter giving \$10,000,000 to establish a fund for pensioning professors, denominational institutions, on the one hand, and state institutions, on the other, were excluded. In the act of incorporation, however, the question of the state institutions was left open, and it was at one time reported by the newspapers that Mr. Carnegie would add five million dollars to the foundation in order that they might be included. But it now appears that the opposite policy will be followed. The documents on the subject presented to the trustees have been printed as a bulletin of the Carnegie Foundation. This bulletin, in addition to giving the grounds that have been urged for and against the policy of granting pensions to professors in the state institutions, contains some interesting data in regard to the development of these institutions.

The executive committee of the National Association of State Universities drew up a statement for the trustees in which they urge the following reasons for including these universities under the auspices of the fund: State universities are not controlled by religious denominations; they maintain college standards based on the high school; they have an assured income equal to the productive endowment required for private foundations; state institutions can not establish a pension fund as this might raise the whole question of pensions for state officers; the omission of these institutions discriminates against the professors who have served them; the plan would not weaken support by the states. Memoranda in favor of granting allowances

were also presented by Dr. Maurice Hutton, acting president of the University of Toronto, and by Professor Henry T. Eddy, dean of the graduate school of the University of Minnesota.

Dr. Henry S. Pritchett, president of the foundation, discusses these papers, and comes to an adverse conclusion. He holds that from the point of view of general policy, professors in the state institutions should receive retiring allowances, but that these should be established by the states themselves, as the granting of allowances by a private agency might lessen the sense of responsibility of the states for educational support. He states that to add to the list of accepted institutions all state universities would be to complete the list of institutions for which the foundation can provide an adequate retiring system. He holds that the award of pensions to a large number of representative institutions by the foundation will make the plan part of the American Educational System, which other institutions will necessarily follow.

It may be that in this matter the trustees of the Carnegie Foundation, nearly all of whom are presidents of private institutions, are not entirely disinterested. Some of them have given occasion for such inference by their attitude toward a national university, which Mr. Carnegie at one time planned to endow. In the establishment of libraries, Mr. Carnegie has not been indisposed to cooperate with institutions supported by taxation. However, it does not follow that in the end it would have been to the advantage of the state institutions to have been placed under the Carnegie Foundation. There are dangers, as well as advantages in centralization and uniformity. It by no means follows that compulsory retirement at the age of sixty-five, on part salary is the best plan. Perhaps the state universities may adopt the German system, by

which the appointment of a professor is for life, he being excused from active service when disabled by illness or old age.

SCIENTIFIC ITEMS

WE record with regret the deaths of Sir Benjamin Baker, F.R.S., the eminent British engineer; of Dr. Alexander Buchan, F.R.S., the Scottish meteorologist; of Sir Joseph Fayrer, known for his pathological work in India, and Dr. Charles Féré, known for his researches in neurology and psychiatry.

THE honorary freedom of the City of London is to be conferred on Lord Lister.—The gold medal of the Linnean Society, London, has been awarded to Dr. Melchior Treub, director of the Botanical Garden at Buitenzorg.

A SECOND series of tablets was unveiled in the Hall of Fame, of New York University, on Memorial Day, May 30. Addresses were made by Governor Hughes, of New York, and Governor Guild, of Massachusetts. Among the twelve tablets unveiled was one in memory of Maria Mitchell, the astronomer, and one in memory of Louis Agassiz. The tablet in honor of

Agassiz was unveiled under the auspices of the American Association for the Advancement of Science with brief addresses by Dr. Charles D. Walcott, secretary of the Smithsonian Institution, and Dr. Edward S. Morse, director of the Peabody Institute of Science.

THE committee of one hundred, appointed by the American Association for the Advancement of Science to further the promotion, of national interest in health, met in New York City, April 18, and organized by the adoption of rules, the election of officers and the appointment of an executive committee. Professor Irving Fisher, of New Haven, presided as the temporary chairman and was subsequently elected president. Ten vice-presidents were elected, as follows: President Charles W. Eliot, Harvard University; Dr. Felix Adler, New York; Dr. William H. Welch, Baltimore; Rev. Lyman Abbott, New York; President James B. Angell, University of Michigan; Miss Jane Addams, Chicago; Hon. Joseph H. Choate, New York; Rt. Rev. John Ireland, St. Paul; Hon. Ben. B. Lindsey, Denver; Hon. John D. Long, Boston.

THE POPULAR SCIENCE MONTHLY

AUGUST, 1907

THE PROBLEM OF AGE, GROWTH AND DEATH

BY CHARLES SEDGWICK MINOT, LL.D., D.SC.

JAMES STILLMAN PROFESSOR OF COMPARATIVE ANATOMY IN THE HARVARD MEDICAL SCHOOL

II. CYTOMORPHOSIS. THE CELLULAR CHANGES OF AGE

Ladies and Gentlemen: I endeavored in my last lecture to picture to you, so far as words could suffice to make a picture, something of the anatomical condition of old age in man, and to indicate to you further that the study merely of those anatomical conditions is not enough to enable us to understand the problem we are tackling, but that we must in addition extend the scope of our inquiry so that it will include animals and plants, for since in all of these living beings the change from youth to old age goes on, it follows that we can hardly expect an adequate scientific solution of the problem of old age unless we base it on broad foundations. By such breadth we shall make our conclusion secure, and we shall know that our explanation is not of the character of those explanations which I indicated to you in the last lecture, which are so-called 'medical,' and are applicable only to man, but rather will have in our minds the character of a safe, sound and trustworthy biological conclusion. The problem of age is indeed a biological problem in its broadest sense, and we can not study, as we now know, the problem of age without including in it also the consideration of the problems of growth and the problems of death. I hope to so entice you along in the consideration of the facts, which I have to present, as to lead you gently but perceptibly to the conclusion that we can with the microscope now recognize in the living parts of the body some of those characteristics which result in old age. Old age has for its foundation a condition which we can actually make visible to the human eye. As a step towards this conclusion, I desire to show you this evening something in regard to the microscopic structure of the human body.

We now know that the bodies of all animals and plants are constituted of minute units so small that they can not be distinguished by the naked eye, although they can be readily demonstrated by the microscope. These units have long been known to naturalists by the name of cells. The discovery of the cellular constitution of living

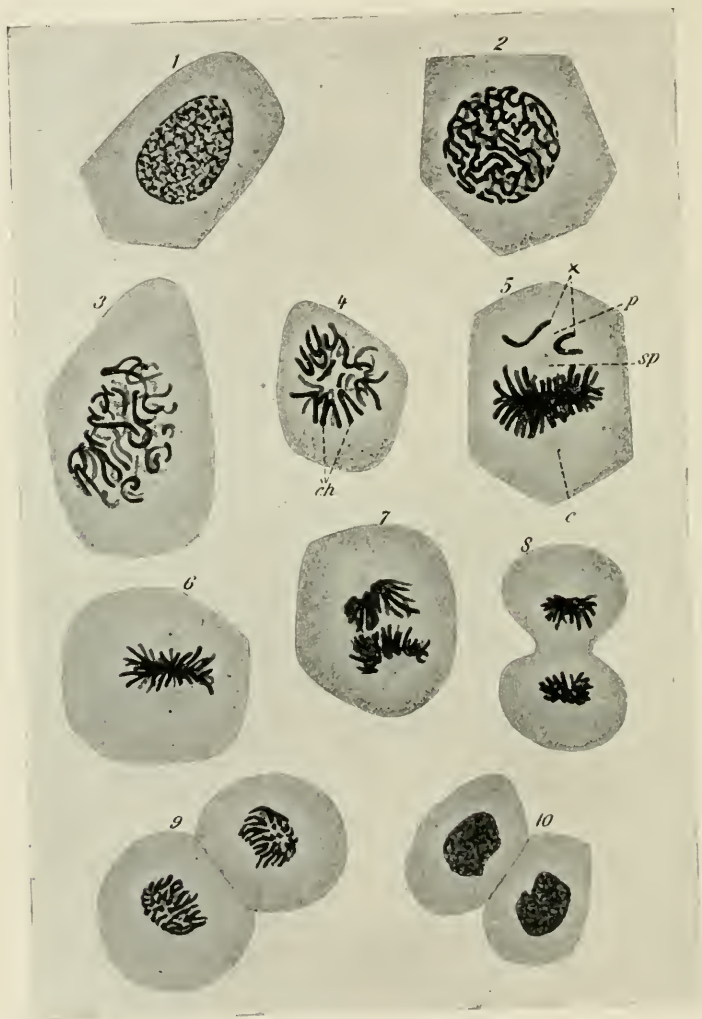


FIG. 3. CELLS FROM THE MOUTH (ORAL EPITHELIUM) OF THE SALAMANDER, TO SHOW THE PHASES OF CELL DIVISION OR MITOSIS.

bodies marks one of the great epochs in science, and every teacher who has had occasion to deal in his lectures with the history of the biological sciences finds it necessary to dwell upon this great discovery. It was first shown to be true of plants, and shortly after likewise of animals. The date of the latter discovery was 1839. We owe it to

Theodor Schwann, whose name will therefore ever be honored by all investigators of vital phenomena. What the atom is to the chemist, the cell is to the naturalist. Every cell consists of two essential parts. There is an inner central kernel which is known by the technical name of nucleus, and a covering mass of living material which is termed the protoplasm and constitutes the body of the cell. I will now call for the first of our lantern slides to be thrown upon the screen. It presents to you pictures of the cells as they are found lining the mouth of the European salamander. The two figures at the top illustrate very clearly the elements of the cell. The protoplasm forms a mass, offering in this view no very distinctive characteristics, and therefore offering a somewhat marked contrast with the nucleus which presents in its interior a number of granules and threads. Every nucleus consists of a membrane by which it is separated from the protoplasm, and three internal constituents: First, a network of living material, more or less intermingled with which is a second special substance, chromatin, which owes its name to the very marked affinity which it displays for the various artificial coloring matters which are employed in microscopical research. The third of the internal nuclear constituents we may call the sap, the fluid material which fills out the meshes of the network. Later on we shall have occasion to study somewhat more carefully the principal variations which nuclei of different kinds may present to us, and we shall learn from such study that we may derive some further insight into the rapidity of development and the nature of the changes which result in old age. While the picture is upon the screen, I wish to call your attention to the other figures which illustrate the process of cell multiplication. As you regard them you will notice in the succession of illustrations that the nucleus has greatly changed its appearance. The substance of the nucleus has gathered into separate granules, each of which is termed a chromosome. These chromosomes are very conspicuous under the microscope, because they absorb artificial stains of many sorts with great avidity and stand out therefore conspicuously colored in our microscopic preparations. They are much more conspicuous than is the substance of the resting nucleus. And this fact, that we can readily distinguish the dividing from the resting nucleus under the microscope, we shall take advantage of later on, for it offers us a means of investigating the rate of growth in various parts of the body. I should like, therefore, to emphasize the fact at the present time sufficiently to be sure that it will remain in your minds until the later lecture in which we shall make practical use of our acquaintance with it. It is unnecessary for our purposes to enter into a detailed description of the complicated processes of cell division. But let me point out to you that the end result is that where we have one cell we get as the result of division—two; but the

two divided cells are smaller than the mother cell and have smaller nuclei. They will, however, presently grow up and attain the size of their parent.

Every cell is a unit both anatomically and physiologically. It has a certain individuality of its own. In many cases cells are found to be isolated or separated completely from one another. But, on the other hand, we also find numerous instances in which the living substance of one cell is directly continuous with that of another. When the cells are thus related, we speak of the union of cells as *syncytium*. Of this I offer you an illustration in the second picture upon the screen, which represents the embryonic connective tissue of man. In this you can see the prolongations of the protoplasm of a single cell body uniting with the similar prolongations from other cell bodies, the cells themselves thus forming, as it were, a continuous network with broad meshes between the connecting threads of protoplasm. The spaces or meshes are, however, not entirely vacant, but contain fine lines which correspond to the existence of fibrils, which are characteristic of connective tissue and at the stage of development represented in this picture, are beginning to appear. It is fibrils of this sort which we find as the main elements in the constitution of sinews and tendons, as, for instance, the tendon of Achilles, at the heel. In a very young body we find there are but few fibrils; in the adult body an immense number.

There is, in fact, as you probably all know, a constant growth of cells; and this growth implies also, naturally, their multiplication. There has been in each of us an immense number of successive cell



FIG. 4. EXAMPLE OF A SYNCYTIUM. Embryonic connective tissue from the umbilical cord of a human embryo of about three months, magnified about 400 diameters, *c, c*, cells; *f*, intercellular fibrils.

generations, and at the present time a multiplication of cells is going on in every one of us. It never entirely ceases as long as life continues. The development of the body, however, does not consist only of the growth and multiplication of cells, but also involves changes in the very nature of the cells, alterations in their structure. Cells in us are of many different sorts, but in early stages of development they are of few sorts. Moreover, in the early stages we find the cells all more or less alike. They do not differ from one another. Hence comes the technical term of differentiation, to designate the modifications which cells undergo with advancing age. At first cells are alike; in older individuals the cells have become of different sorts, they have been differentiated into various classes. This whole phenomenon of cell

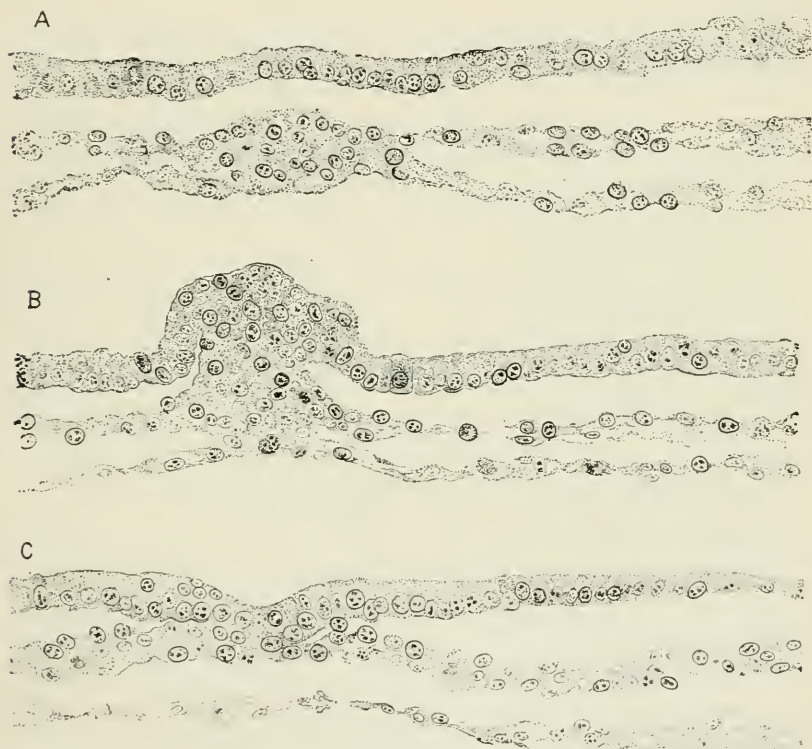


FIG. 5. THREE TRANSVERSE SECTIONS THROUGH A RABBIT EMBRYO OF SEVEN AND ONE HALF DAYS, from series 622 of the Harvard Embryological Collection. A, section 247 across the anterior part of the germinal area. B, section 260 across the middle region of the germinal area. C, section 381, through the posterior part of the germinal area. Magnified 300 diameters.

change is comprehensively designated by the single word, cytomorphosis, which is derived from two Greek words meaning *cell* and *form*, respectively. A correct understanding of the conception *cytomorphosis* is an indispensable preliminary to any comprehension of the phenomena of

development of animal or plant structure. I shall endeavor, therefore, now to give you some insight into the phenomena of cytomorphosis as regarded by the scientific biologist. The first cells which are produced are those which form the young embryo. We speak of them, therefore, as embryonic cells, or cells of the embryonic type. Our next picture illustrates the actual character of such cells as seen with the microscope, for it represents a series of sections through the body of a rabbit embryo, the development of which has lasted only seven and one half days. You will notice at once the simplicity of the structure. There are not yet present any of those parts which we can properly designate as organs. The cells have been produced by their own multiplication and are not yet so numerous but that they could be readily actually counted. They are spread out in somewhat definite layers or sheets, but beyond that they show no definite arrangement which is likely to attract your attention. That which I wish you particularly to observe is that in every part of each of these sections the cells appear very much alike. The nuclei are all similar in character, and for each of them

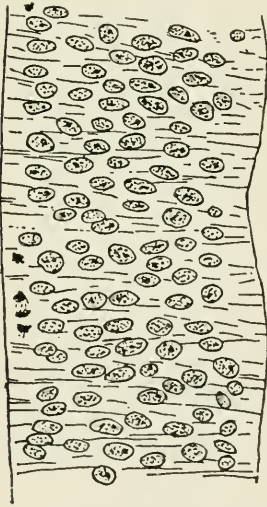


FIG. 6. PORTION OF A TRANSVERSE SECTION OF THE SPINAL CORD OF A HUMAN EMBRYO OF FOUR MILLIMETERS. Harvard Embryological Collection, series 714. The spinal cord at this stage is a tubular structure. The figure shows a portion of the wall of the tube; the lefthand boundary of the figure corresponds to the inner surface of the tube.

there is more or less protoplasm; but the protoplasm in all parts of these young rabbits is found to be very similar; and indeed if we should pick out one of these cells and place it by itself under the microscope, it would be impossible to tell what part of the rabbit embryo it had been taken from, so much do all the cells of all the parts resemble one another. We learn from this picture that the embryonic cells are all very much alike, simple in character, have relatively large nuclei, and only a moderate amount of protoplasm for each nucleus to complete the cell.

Very different is the condition of affairs which we find when we turn to the microscopic examination of the adult. Did time permit it would be possible to study a succession of stages and show you that the condition which we are about to study as existing actually in the adult is the result of a gradual progress and that in successive stages of the individual we can find successive stages of cell change; but it will suffice for our immediate purpose to consider the results of differentiation as they are shown to us by the study of the cells of

the adult. I will have thrown upon the screen for you a succession of pictures illustrating various adult structures. The first is, however, a section of the embryonic spinal cord in which you can see that much of the simple character of the embryonic cells is still kept. All parts of the spinal cord, as the picture shows, are very much alike, and the nuclei of the cells composing the spinal cord at this stage are all essentially similar in appearance. What a contrast this forms with our next picture, which shows us an isolated so-called motor nerve cell from the adult spinal cord. It owes its name motor to the fact that it produces a nerve fiber by which motor impulses

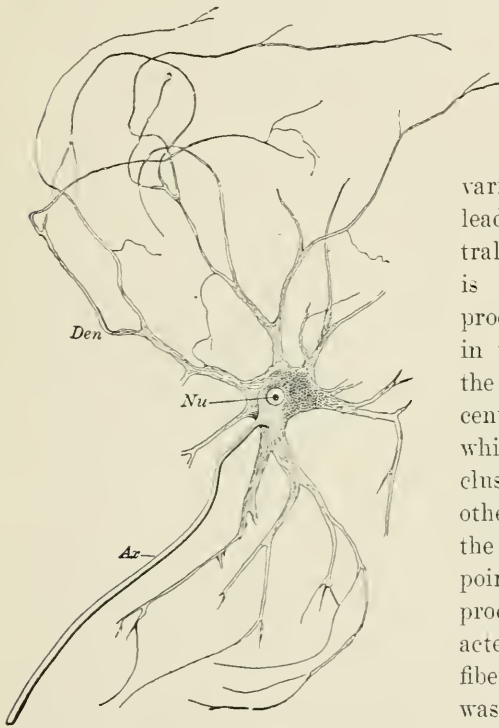


FIG. 7. COPY OF THE ORIGINAL FIGURE FROM THE MEMOIR OF DEITERS, in which the proof of the origin of the nerve fibers directly from the nerve cells was first published. The memoir is one of the classics of anatomy. It was issued posthumously, for the author died young to the great loss of science. The figure represents a single isolated motor nerve cell from the spinal cord of an ox. The single unbranched axon Ax, is readily distinguished from the multiple branching dendrites.

are conveyed from the spinal cord to the muscles of the body. The cell has numerous elongated branching processes stretching out in various directions, but all leading back towards the central body in which the nucleus is situated. These are the processes which serve to carry in the nervous impulses from the periphery towards the center of the cell, impulses which in large part, if not exclusively, are gathered up from other nerve cells which act on the motor element. At one point there runs out a single process of a different character. It is the true nerve fiber, and forms the axis, as it was formerly termed; or axon, as it is at present more usually named, of the nerve fiber as we encounter it in an ordinary nerve. This single thread-like prolongation of the nerve cell is likewise constituted by the living protoplasm and serves to carry the impulses

away from the cell body and transmit them ultimately to the muscle fibers which are to be stimulated to contraction. In the embryonic

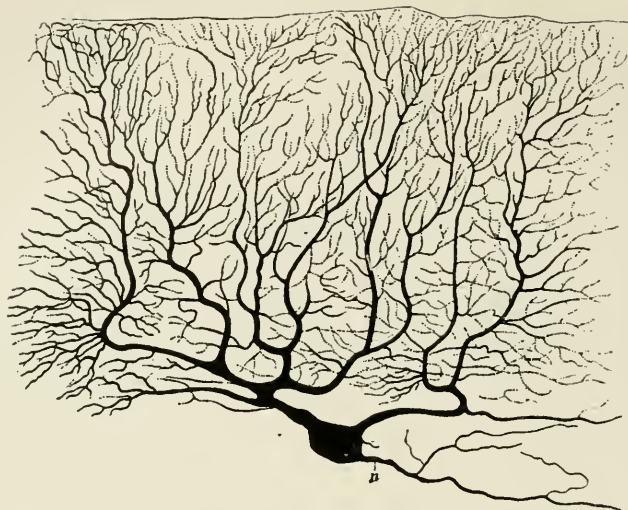


FIG. 8 A LARGE CELL FROM THE SMALL BRAIN (CEREBELLUM) OF A MAN. It is usually called a Purkinje's cell. It was stained black throughout by what is known as the Golgi silver method, hence shows nothing of its internal structure. After von Kölliker.

spinal cord none of these processes existed, and the amount of the protoplasm in the nerve cell was very much smaller. As development progressed, not only did the protoplasm body grow, but the processes gradually grew out. Some of them branched so as to better receive and collect the impulses; one of them remained single and very much elongated, and acquired a somewhat different structure in order to serve to carry the nervous impulses away. The third picture¹ shows us a section through the spinal cord of an adult fish. It has been treated by a special stain in order to show how certain elements of the spinal cord acquire a modification of their organization by which they are adapted to serve as supports for the nervous elements proper. They play in the microscopic structure the same supporting rôle which the skeleton performs in the gross anatomy of the body as a whole. They do not take an active part in the nervous functions proper. None of the appearances which this figure offers for our consideration can be recognized in any similar preparation of the embryonic cord. Obviously, then, from the embryonic to the adult state in the spinal cord there occurs a great differentiation. That which was alike in all its parts has been so changed that we can readily see that it consists of many different parts. A striking illustration of this is afforded by the next picture, which represents one of the large nerve cells which occur in the small brain, or cerebellum, that portion of the central nervous system which the physiologists have demon-

¹The illustration referred to is not reproduced in the text.

strated to be particularly concerned in the regulation and coordination of movements. These large cells occur only in this portion of the

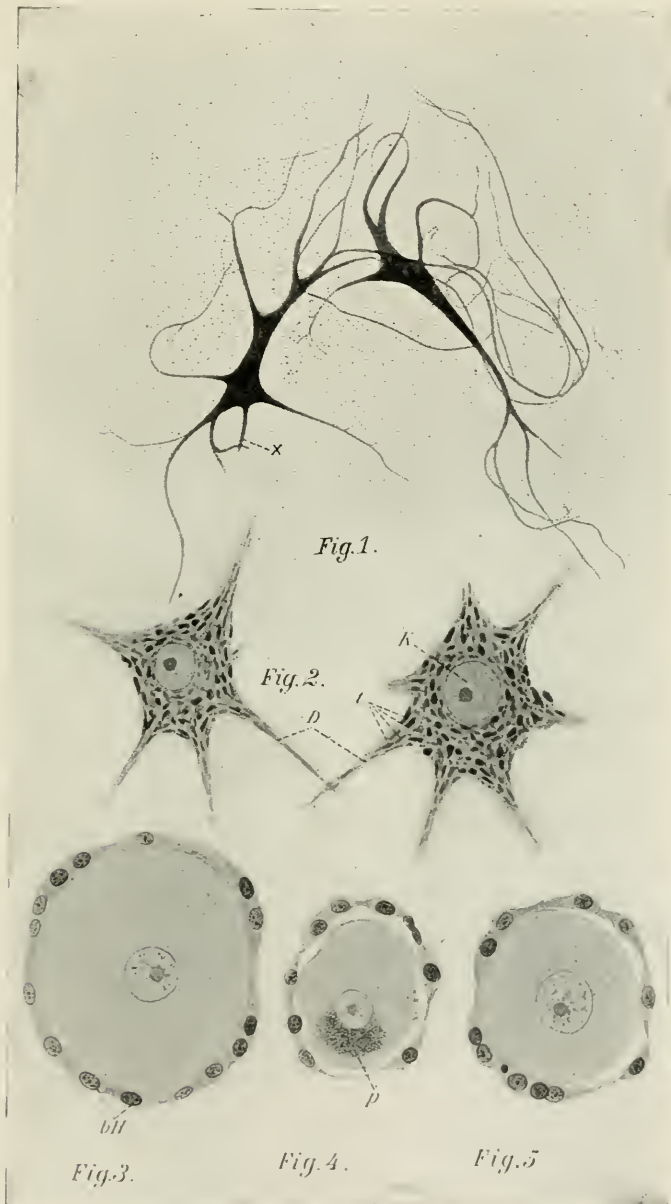


FIG. 9 VARIOUS KINDS OF HUMAN NERVE CELLS, AS DESCRIBED IN THE TEXT.
After Sobotta.

brain, and, as you see, differ greatly in appearance from the motor cells of the type which we were considering a few moments ago. And, again,

another picture illustrates yet other peculiarities of the adult nerve cells. The upper figures in this plate are taken from cells which have been colored uniformly of a very dark hue, in consequence of which

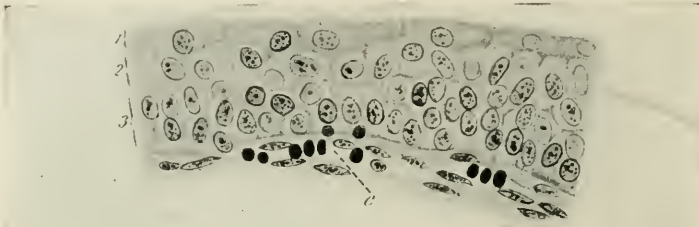


Fig. 1.

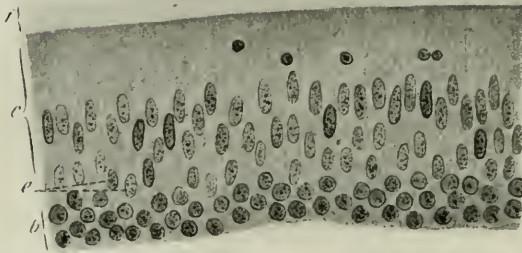


Fig. 2.

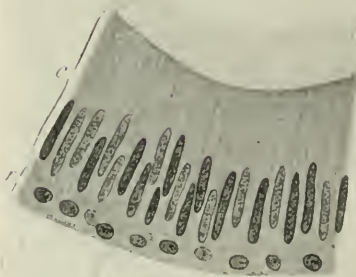


Fig. 3.

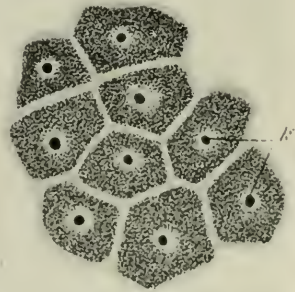


Fig. 4.

FIG. 10. SECTIONS OF FOUR SORTS OF EPITHELIUM. After Sobotta.

they are rendered so opaque that the nucleus which they really contain is hidden from our view. But the deep artificial color makes it easy to follow out the form of the cells and the ramifications of their long processes. In the middle figures we have cells which have been stained by another method which brings out very clearly to the eye the fact

that in the protoplasm of the cell there are scattered spots of substance of a special sort. No such spots can be demonstrated in the elements of the young embryonic nerve cells. To some fanciful observers the spots, thus microscopically demonstrable in the nerve cells, recall the spots which appear on the skin of leopards, and hence they have bestowed upon these minute particles the term tigroid substance. The bottom figures represent the kind of nerve cells which occur upon the roots of the spinal nerves. It is unnecessary to dwell upon their appearance, as the mere inspection of the figures shows at once that they differ very much indeed from the other nerve cells we have considered. We pass now to another group of structures, the tissues which are known by the technical name of epithelia. You can notice immediately in the figures from the skin that the appearances are very different from those we have encountered in contemplating the cells of the nervous system. And you can readily satisfy yourselves by the comparison with the various figures now before you, of the fact that these epithelia are unlike one another. The figures represent epithelium, respectively, first from the human ureter; second, from the respiratory division of the human nose; third, from the human ductus epididymidis, and fourth, from the pigment layer of the retina of the cat. We turn now to a representation of a section of one of the orbital glands. This is very instructive because we see not only that the cells which compose the gland have acquired a special character of their own, but also that they are not uniform in their appearances. This lack of uniformity is due chiefly to the fact that the cells change their appearance according to their functional state. We can actually see in these cells under the microscope the material imbedded in their protoplasmic

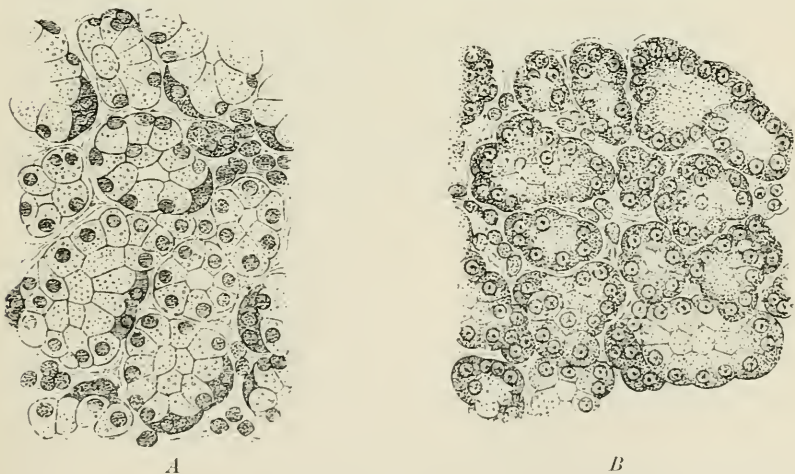


FIG. 11. TO SHOW THE ORBITAL GLANDS, *A*, with the material to form the secretion accumulated within the cells. *B*, after loss of the material through prolonged secretion. From R. Heidenhain after Lavdowsky.

bodies out of which the secretion, which is to be poured forth by the cells, is to be manufactured. So long as that material for the secretion is contained in the cells, the cells appear large, and their protoplasmic bodies do not readily absorb certain of the staining matters, which the microscopist is likely to apply to them. When, however, the accumulated raw material has been changed into the secretion and discharged from the gland, the cell is correspondingly reduced in bulk, and as you see in this figure, it then takes up the stain with considerable avidity, as does also the nucleus which has likewise become reduced in size. These facts are very instructive for us, since they prove conclusively that with the microscope we can see at least part of the peculiarities in cells which are correlated with their functions. We can actually observe that the cells of the salivary glands are able to produce their peculiar secretion because they contain a kind of substance which in the embryonic cell does not appear at all. There is a visible differentiation of these salivary cells from the simple stage of the embryonic cells. Something similar to this can be recognized in the next of our pictures representing a section of the gland properly known as the pancreas, but which is sometimes termed the abdominal salivary gland for the reason that it somewhat resembles the true salivary. In the cells of the pancreas also we can see the material, which is to produce the secretion, accumulated in the inner portion of the cell, and when it is so accumulated the cell appears enlarged in size and the nucleus is driven back towards the outer end of the cell where some unaltered protoplasm is also accumulated. When this raw material is turned

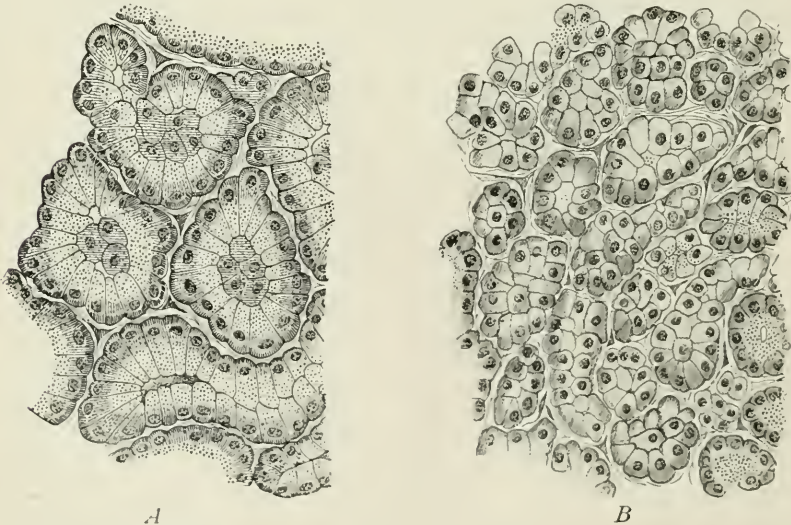


FIG. 12. TWO SECTIONS OF THE PANCREATIC GLAND OF A DOG. *A*, the cells are enlarged by the accumulation of material to form the secretion. *B*, the cells are shrunk because there has been prolonged secretion and part of their substance is lost. From R. Heidenhain.

over into secretion by a chemical change, it is discharged from the cell, the cell loses in volume and in its shrunken state presents a very different appearance, as is shown at *B* in the figure. It is necessary for the cells to again elaborate the material for secretion before they can a second time become functionally active. Here we have something of the secret of the production of the various juices in the body revealed to us. Other excellent examples of the differentiated condition of the cells are afforded us by the examination of hairs, of which I will show you two pictures. The first represents a section through the human

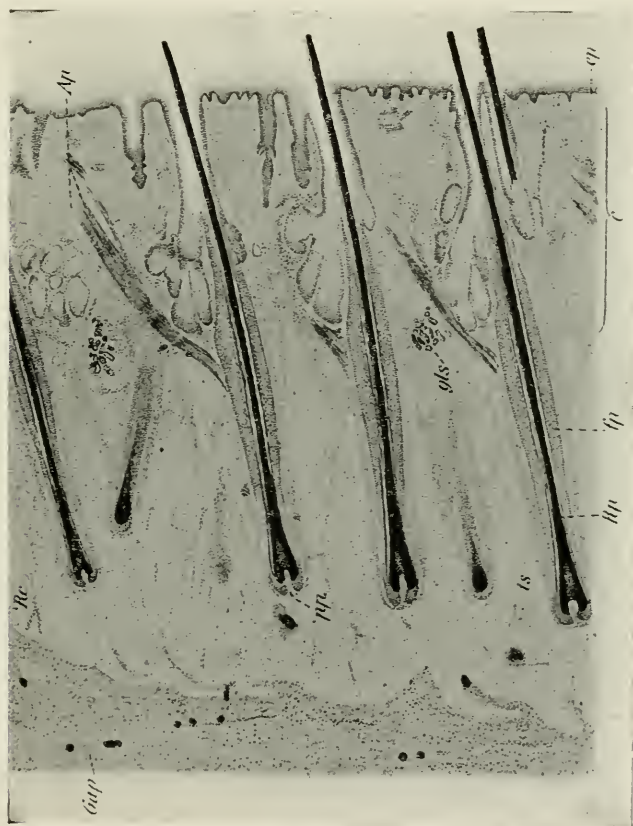


FIG. 13. SECTION OF THE HUMAN SKIN, MADE SO THAT THE HAIRS ARE CUT LENGTHWISE.

skin taken in such a way that the hairs are themselves cut lengthwise and you can see not only that each hair consists of various parts, but also that the cells in these parts are unlike. The follicles within the skin in which the hair is lodged likewise have walls with cells of various sorts. It may interest you also to point out in the figure the little muscle which runs from each hair to the overlying skin, so disposed that when the muscle contracts the particular hair will stand up on

end." Still more clearly does the variety of cells which actually exists in a hair show in the following picture, which represents a cross-section of a hair, and its follicle, but more highly magnified than were the hairs in the previous figure. The adult body consists of numerous organs. These are joined together and kept in place by intervening

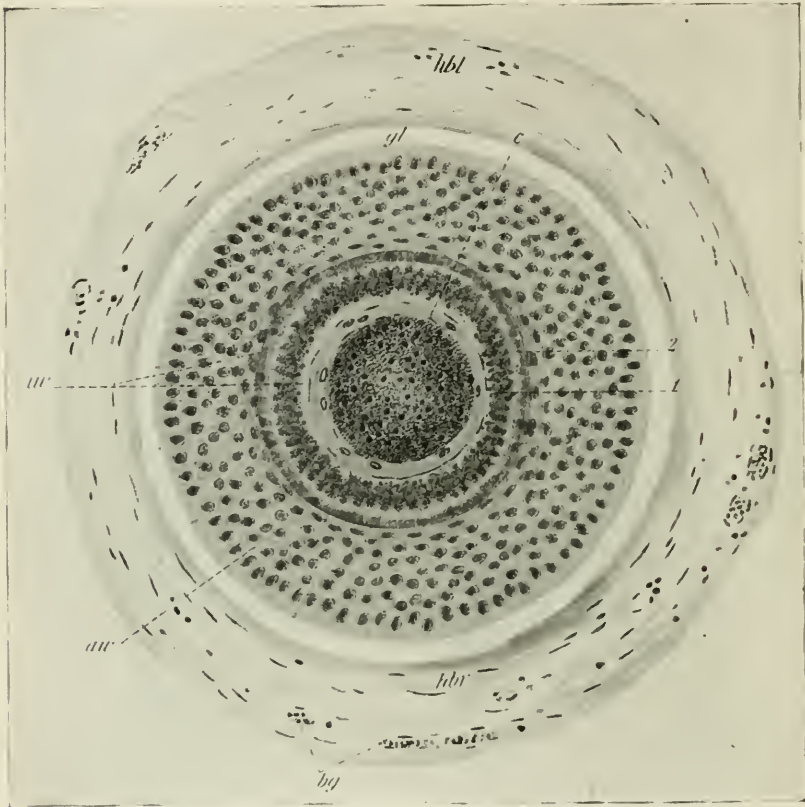


FIG. 14. CROSS SECTION OF THE ROOT OF A HAIR.

substance. The organs themselves consist of many separate parts which are also joined by a substance which keeps them in place. This substance has received the appropriate name of connective tissue. We find in the adult that it consists of a considerable number of structures. There are cells and fibers of more than one kind, which have been produced by the cells themselves. There is more or less substance secreted by the cell which helps to give consistency to the tissue. In some cases this substance which is secreted by the cells becomes tougher and acquires a new chemical character. Such is the case, for instance, with cartilage. Or, again, you may see a still greater chemical metamorphosis going on in the material secreted by the cells in the case of bone, where the substance is made tougher and stronger by the deposit

of calcareous material. Nothing like cartilage, nothing like bone, exists in the early state of the embryo. They represent something different and new. The next of our illustrations shows us a muscle fiber of the sort which serves for our voluntary motions, which is connected typically with some part of the skeleton. These muscle fibers are elongated structures. Each fiber contains a contractile substance different from protoplasm, and which exists in the form of delicate fibrils which run lengthwise in the muscle fibers, and is so disposed, further, that a series of fine lines are produced across the fiber itself, each line corresponding with a special sort of material different from the original protoplasm. These cross lines give to the voluntary muscle fibers a very characteristic appearance, in consequence of which they are commonly designated in scientific treatises by the term striated. A striated muscle fiber is that which is under the control of our will. It should perhaps be mentioned that the muscle fibers of the heart are also striated, though they differ very much in other respects from the true voluntary muscles. And last of all for this series of demonstrations, I have chosen a representation of the retina. One can see at the top of the figure the peculiar cylindrical and developing projections, which are characteristic of a retina, projections which are of especial interest because they represent the apparatus by which the rays of light are transformed into an actual sensory perception.

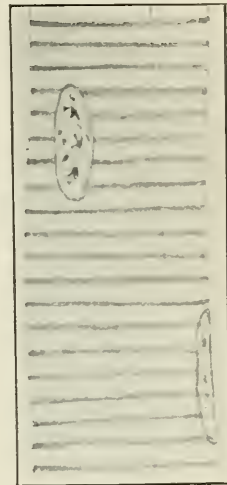


FIG 15. PART OF A MUSCLE FIBER OF THE HUMAN TONGUE TO SHOW THE CROSS STRIATIONS. Two nuclei are included, one of which is shown at the edge of the fiber, the other in surface view. In the adult striated muscle fibers of mammals the nuclei are superficially placed.

After this has been accomplished, the perception is transmitted into the interior substance of the retina, and by the complication of the figure you may judge a little of the complication of the arrangements by which the transmission through this sensory organ is achieved, until the perception is given off to a nerve fiber and carried to the brain. There is not time to analyze all I might present to you of our present knowledge concerning the structure of the retina. But it will, I think, suffice for purposes of illustration to call your attention to the complicated appearance of the section as a whole and to assure you that nothing of the sort exists in the early stage of the embryo. To recapitulate, then, what we have learned from the consideration of these pictures, we may say that in place of uniformity we now have diversity. It should be added, to make the story complete, that the establishment of this diversity has been gradually brought about, and that that which

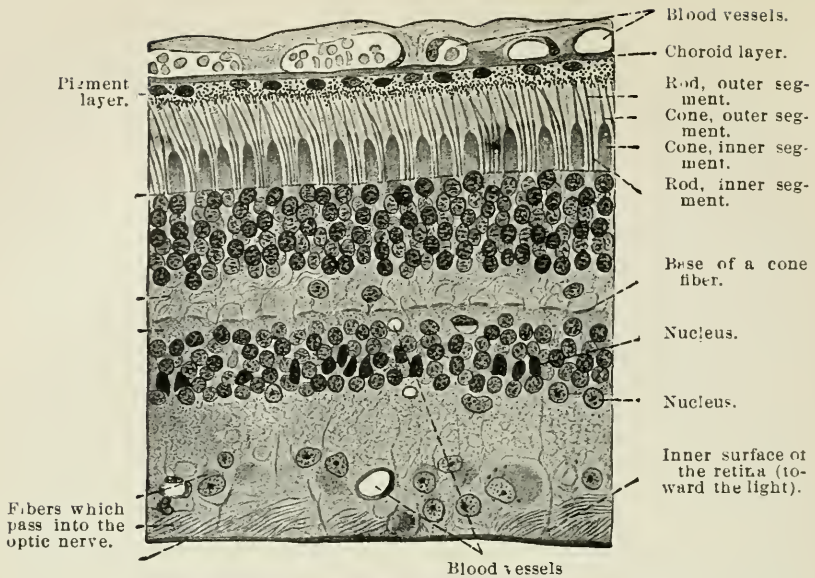


FIG. 16. SECTION OF A HUMAN RETINA, from Stühr's Histology, sixth American edition. Although the retina is very thin it comprises no less than twelve distinct layers: the outermost layer is highly vascular. The pigment layer prevents the escape of light. The rods and cones convert the light waves into a sensory impulse, which is transmitted through the remaining layers of the retina to the optic nerve. The total structure is extremely complicated.

we call development is in reality nothing more than the making of diversity out of uniformity. It is a process of differentiation. Differentiation is indeed the fundamental phenomenon of life; it is the central problem of all biological research, and if we understood fully the nature of differentiation and the cause of it, we should have probably got far along towards the solution of the final problem of the nature of life itself.

The size of animals deserves a few moments of our time, for it is intimately connected with our problem of growth and differentiation. Cells do not differ greatly from one another in size. The range of their dimensions is very limited. This is particularly true of the cells of any given individual animal. Recent careful investigations have been made upon the relation of the size of cells to the size of animals, and it has been found that animals are not larger, one than another, because their cells are larger, but because they have more of them. This statement must be understood with certain necessary reservations. There are some kinds of animals, like the star-fish, which have very small cells; others, like frogs and toads, which have large cells; so that a star-fish of the same bulk as a given frog would contain a great many more cells. Our statement is true of allied animals. For example, a large frog differs from a small frog, or a large dog from a small dog by the number of the cells. An important exception to this law is offered for our consideration by the cells of the central nervous

system, the nerve cells properly so called. This is demonstrated by the slide now before us, which shows us corresponding motor nerve cells of twelve different animals arranged in the order of their size—the elephant, the cow, the horse, man, the pig, the dog, the baboon, the cat, the rabbit, the rat, the mouse, and a small bat. You recognize im-

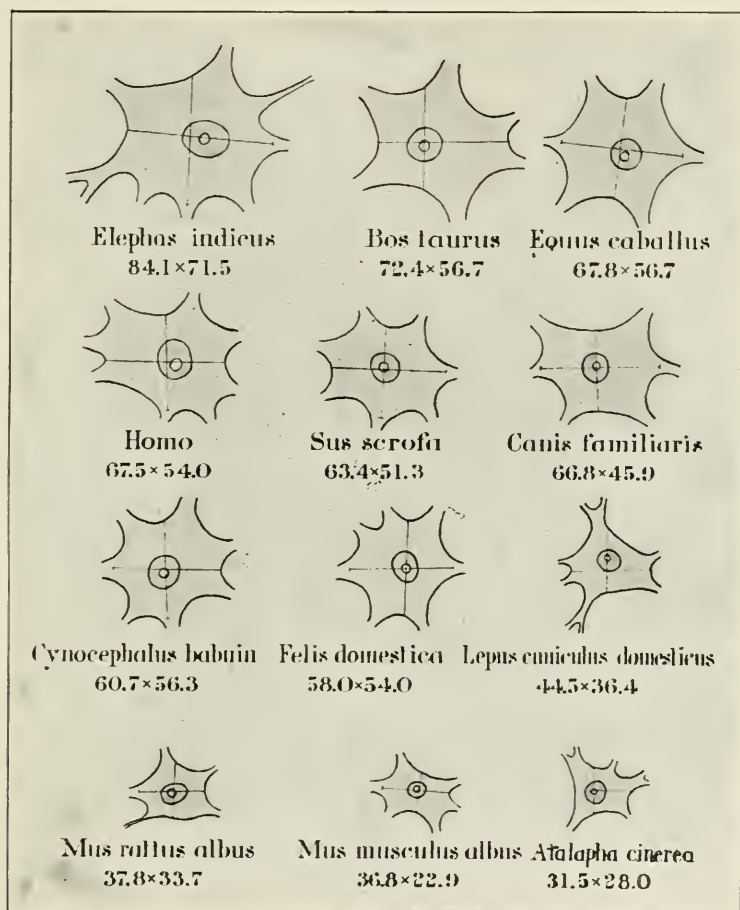


FIG. 17. MOTOR NERVE CELLS OF VARIOUS MAMMALS, all from the cervical region of the spinal cord. The cells are represented, all uniformly magnified. After Irving Hardesty.

mediately that there is a proportion between the size of these cells and the size of the respective species of animals. To a minor degree, but much less markedly, there is a difference in the caliber and length of the muscle fibers. But with these exceptions our statement is very nearly exactly true, that the difference in size of animals does not involve a difference in the size of their cells. For the purpose of the study of development, which we are to make in these lectures, this uni-

fermity in the size of cells is a great advantage, and enables us to speak in general terms in regard to the growth of cells, and renders it superfluous to stop and discuss for each part of the body the size of the cells which compose it, or to seek to establish different principles for different animals because their cells are not alike in size.

Now we pass to a totally different aspect of cell development, that which is concerned with the degeneration of cells. For we find that,



FIG. 18. CHANGES IN THE NERVE CELLS WITH AGE.

after the differentiation has been accomplished, there is a tendency to carry the change yet further and to make it so great that it goes beyond perfection of structure, so far that the deterioration of the cell comes as a consequence. Such cases of differentiation we speak of as a degeneration, and it may occur in a very great number of ways. Very frequently it comes about that the alteration in the structure of the cell goes so far in adapting it to a special function that it is unable to maintain itself in good physiological condition, and failing to keep up its own nourishment it undergoes a gradual shrinkage which we call atrophy. A very good illustration of this, and a most important one, is offered us by the changes which go on in the nerve cells in extreme old age. This is beautifully illustrated by the two pictures which are now before us, copied from investigations of Professor Hodge, of Clark University. The two figures represent human nerve cells taken from the root of a spinal nerve. The left-hand figure shows these cells as they exist in their full maturity; the right-hand figure, as they appear in a person of extreme old age. In the latter you will readily notice that the cells have shrunk and no longer fill

the spaces allotted to them, the nuclei have become small, and the protoplasm has changed its appearance very strikingly because there have been deposited in it granules of the pigment which impart to these cells an appearance very different from that which they had in their maturity when their functional powers were at their maximum. You will notice also in other parts of the right-hand figure that the atrophy of the cells has led on to their disintegration, that they are breaking down, being destroyed, and that the result of their breaking down will ultimately be their disappearance. Thus the atrophy of a cell may lead to its death. The other two figures¹ upon the screen show us the brain of the humble bee. On the left is the brain of the bee in the condition in which we find it when the bee first emerges from the pupa or chrysalis. The cells are then in a fine physiological condition, but in a few weeks at most the bee becomes old and in the space which belongs to each cell we find only its shrunken and atrophied remnants, the nucleus greatly reduced in volume, and an irregular mass of protoplasm shrunk together around it. These cells have likewise undergone an atrophy and are on their way to death. In other cases we find that there is a change going on which we call necrobiosis, which means that the cells continue to live, but change their chemical organization so that their substance passes from a living to a dead state. No more perfect illustration of this sort of change can be found than that which is afforded by the skin. In the deep layer of the outer skin are the living and growing parts, which we all know from experience are sensitive. As these multiply some of them move up towards the surface; and they are continually shoved nearer and nearer the surface by the growth of the cells underneath. They finally become exposed at the surface by the loss of the superficial cells which preceded them. During this migration the protoplasm of each cell, which was alive, is changed chemically into a new substance which we call keratin, or in common language, horny substance. Ultimately the cell protoplasm becomes nothing but horny substance and is absolutely dead. Here life and death play together and go hand in hand. Hence the term necrobiosis, life and death in one. Another form of degeneration which occurs in many cases is of great interest because it seems as if the cells were making a last great effort; and their final performance is one of enlargement. They become greater in size than before; but there will follow a disintegration of these cells also; and they break down and are lost. This form of degeneration is termed hypertrophic, and represents a third type, as I have stated. In all parts of the body degenerative changes are going on, and they represent collectively a third phase in the cytomorphic cycle. But there is yet one more phase, which is needed to complete the story. That is the phase of the

¹ The two figures of the bee's brain are not reproduced in the text.

death and final removal of the cells. The degenerative change always results in the death of the cell. In many cases the dead material is removed merely by being cast off, as is the case with the skin. All the scales which peel off from the outer surface of our body represent little scraps or clusters of cells which are entirely dead; and in the interior of the body, in the intestinal canal, and in the glands of the stomach, we find cells continually dying, dropping off from their place upon the walls, and being cast away. Or if we examine the saliva which comes from the mouth, we detect that that also is full of cells which have died and fallen off from their connection with the body and are thus removed. An even more important method of the removal of cells is by a chemical process in consequence of which the cells are dissolved and disappear before our eyes, very much as marble may disappear from sight under the corrosive action of an acid. Indeed, we know that all the parts of the body, so far as they are alive, produce within themselves a ferment which has a tendency to destroy the living substance itself. The production of these destructive agents is going on at all times, apparently, in all parts of the body, which are alive. A striking illustration of this is offered in the stomach. The digestive juice which is produced in the stomach is capable of attacking and destroying living substance, and any organic material suitable for food which is placed in the stomach will, as we know, be attacked by the gastric juices, dissolved to a certain extent by them, and so destroyed. Why then does the gastric juice not attack the stomach itself? This is but one phase of the problem why the body does not continually destroy itself. It has lately been ascertained by some ingenious physiological investigations that the body not only produces the destructive agents, but also antagonists thereto, anti-compounds which tend to prevent the activity of the destroying factors. The whole problem is one of great interest and importance which calls for very much further investigation before we can be said to have arrived at a clear understanding of it. But it helps us much in our conception of cytomorphosis to know that all portions of the body are endowed with this faculty of destroying themselves, for it enables us to understand how it is possible that after the degeneration of a cell it will be dissolved away. It is merely that the agents of solution which are ordinarily held at bay are no longer restrained, and they at once do their work. There is another, but comparatively rare, mode of cell-destruction. The cells break up into separate fragments, which are then dissolved by chemical means and disappear, by the method of histolysis above described, or else are devoured by the cells, to which reference was made in the first lecture, and which are known by the name of phagocytes, and to which Metchnikoff has attributed so great an importance. It is unquestionable that phagocytes do eat up fragments of cells and of tissues,

and may even attack whole cells. But to me it seems probable that their rôle is entirely secondary. They do not cause the death of cells, but they feed presumably only upon cells which are already dead or at least dying. Their activity is to be regarded, so far as the problem of the death of cells is concerned, not as indicating the cause of death, but as a phenomenon for the display of which the death of the cell offers an opportunity. The subject of the death and disintegration of cells is an exceedingly complex one, and might well occupy our attention for a long time. But it is not permissible to depart from the strict theme which we have before us, and I will content myself, therefore, with throwing upon the screen two tables² which illustrate to us the variations in the death of cells and in their modes of removal which are

²I. DEATH OF CELLS

First. Causes of death.

A. External to the organism:

- (1) Physical (mechanical, chemical, thermal, etc.).
- (2) Parasites.

B. Changes in intercellular substances (probably primarily due to cells):

- (1) Hypertrophy.
- (2) Induration.
- (3) Calcification.
- (4) Amyloid degeneration (infiltration).

C. Changes inherent in cells:

Second. Morphological changes of dying cells.

A. Direct death of cells:

- (1) Atrophy.
- (2) Disintegration and resorption.

B. Indirect death of cells:

- (1) Necrobiosis (structural change precedes final death).
- (2) Hypertrophic degeneration (growth and structural change often with nuclear proliferation precede final death).

Third. Removal of cells.

- A. By mechanical means (sloughing or shedding)
- B. By chemical means (solution).
- C. By phagocytes.

II. INDIRECT DEATH OF CELLS

A. Necrobiosis.

(1) Cytoplasmic changes:

- (a) Granulation.
- (b) Hyaline transformation.
- (c) Imbibition.
- (d) Desiccation.
- (e) Plasmatosis.

(2) Nuclear changes:

- (a) Karyobexis.
- (b) Karyolysis.

B. Hypertrophic degeneration.

(1) Cytoplasmic:

- (a) Granular.
- (b) Cornifying.
- (c) Hyaline.

(2) Paraplasmic:

- (a) Fatty.
- (b) Pigmentary.
- (c) Mucoid.
- (d) Colloid, etc.

(3) Nuclear (increase of chromatin).

known at the present time. These tables are taken from a lecture which I delivered in New York a few years ago, which was subsequently published. If any of you should care to make a closer acquaintance with them they are therefore readily accessible to you. How then, from the standpoint of cytomorphosis ought we to look upon old age? Cytomorphosis, the succession of cellular changes which goes on in the body, is always progressive. It begins with the earliest development, continues through youth, is still perpetually occurring at maturity and in old age. The rôle of the last stage of cytomorphosis, that is, of death in life, is very important, and its importance has only lately become clear to us. I doubt very much if the conception is at all familiar to the members of this audience. Nevertheless the constant death of cells is one of the essential factors of development, and much of the progress which our bodies have made during the years we have lived, has been conditional upon the death of cells. As we have seen, cytomorphosis, when it goes through to the end, involves not only the differentiation but the degeneration and death of the parts. There are many illustrations of this which I might cite to you as examples of the great importance of the destruction of parts. Thus there is in the embryo before any spinal column is formed an actual structure which is termed the notochord. In the young mammalian embryo this structure is clearly present and plays an important part, but in the adult it has entirely disappeared, and its disappearance begins very early during embryonic life. There are numerous blood vessels which we find to occur in the embryo, both those which carry the blood away from the heart and those which bring blood to the heart, which during the progress of development are entirely destroyed, and disappear forever. Knowledge of these is to the practical anatomist and surgeon often of great importance. Vast numbers of the smaller blood vessels which we know commonly by the name of capillaries, exist only for a time and are then destroyed. There is in the young frog, while he is in the tadpole stage, a kidney-like organ, which on account of its position is called the head-kidney, but it exists only during the young stage of the tadpole. There is later produced another kidney which, from its position, is called the middle kidney, and which is the only renal organ found in the adult, for the head kidney entirely disappears in these animals long before the adult condition is reached. In the mammal there is yet a third kidney. We have during the embryonic stage of the mammal always a well-developed excretory organ which corresponds to the middle or permanent kidney of the frog, yet during embryonic life the greater part of this temporary structure is entirely destroyed. It is dissolved away and vanishes, leaving only a few remnants of comparatively little importance in the adult. The new structure, the permanent kidney which we have, takes its place

functionally. Large portions of the tissues, which arise in the embryo, are destroyed at the time of birth, and take no share in the subsequent development of the child. If we follow out with the microscope the various changes which go on in the developing body we see revealed to us a very large number of cases of death of tissues, followed by their removal. Thus the cartilage which exists in the early stages dies and is dissolved away, and its place is taken by bone. Those things which we know as bony elements of the skeleton in the adult, in the embryo exist merely as cartilage, but the cartilage is not converted into bone but it is destroyed and its place taken by bone. There is overlying the heart of a child at birth a well-developed gland known as the thymus. After childhood this undergoes a retrograde development; it becomes gradually absorbed and persists only in a rudimentary condition. With the loss of the teeth occurring during infancy, you are familiar, and know that the first set of teeth are but for a short period, and are to be replaced by the permanent set. In very old persons we see a great deal of the bony material absorbed, and this absorption of the bone is a phenomenon which occurs at almost every period of the development. Portions of the epidermis or outer skin are constantly shed, as is well known, and the loss of hair and the loss of portions of our nails are so familiar to us that we hardly heed them. Of the constant destruction of the cells, which are found in the lining of the intestine, I have already spoken. At all times in the body there is a vast amount of destruction of blood corpuscles going on, a destruction which is physiologically indispensable, for the material which the blood corpuscles furnish is used in many ways. For instance, the pigment which occurs in the hair is supposed to be derived from the chemical substances the use of which the body obtains by destroying blood corpuscles. One of the most familiar instances of destruction is that of the tail of the tadpole. The young frog and the young toad during their larval stages live in the water and each of them is furnished with a nice tail for swimming purposes. As the time approaches for the metamorphosis of the tadpole into the adult, the tail is gradually dissolved away. It is not cast off, but it is literally dissolved, resorbed, and vanishes ultimately altogether.

It is evident that such a vast amount of destruction of living cells could not be maintained in the body without the body going entirely to destruction itself, were there not some device for making good the losses which are thus brought about. We find in fact that there is always a reserve of cells kept to make good the loss which it is essential should be made good. Some losses apparently do not have to be repaired, but the majority of them must be compensated for, and this is done by having in the body a reserve supply of cells which can produce new cells of the sort required. This leads us to consideration of the phenomenon of regeneration and of the repair of parts.

These phenomena we can better take up later in our course, when we have dealt with the general processes of development and growth. From the study of regeneration we shall be able to confirm the explanation of old age, which I want to lay before you. This confirmation is so important that it will be better taken up in a separate lecture, than slipped in now when the hour is nearly by.

Old age, after what I have said, I think you will all recognize as merely the advanced and final stage of cytomorphosis. Old age differs but little in its cytomorphosis from maturity; maturity differs much from infancy; infancy differs very much indeed from the embryo; but the embryo differs enormously from the germ in its cytomorphic constitution. We know that in the early time comes the great change, and this fact we shall apply for purposes of interpretation later on. Cytomorphosis is then a fundamental notion. It gives us in a general law, a comprehensive statement of all the changes which occur in the body. None, in fact, are produced at any period in any of us except in accordance with this general cytomorphic law. There is, first, the undifferentiated stage, then the progressive differentiation; next there follows the degenerative change ending in death, and last of all the removal of the dead cells. Such we may conveniently designate as the four essential stages of cytomorphosis. This cytomorphosis is at first very rapid; afterwards it becomes slower. That is a significant thing. The young change fast; the old change slowly. We shall be able, when we get a little farther along in our study, to see that in differentiation lies the explanation of a great deal of biological knowledge, lies the explanation of our conception of cell structures; and in it also lies not only the explanation of the death of cells, but also, as it seems to me—and this is one of the points that I shall want particularly to bring forward before the close of the course—of general death, that which we mean by death in common parlance, when the continuation of the life of the individual ceases, and is thereafter bodily impossible. The explanation of death is one of the points at which we shall be aiming in the subsequent lectures of the course. Now we know that in connection with age there is always growth. I propose, therefore, in the next lecture, to take up the subject of growth. We shall arrive at some paradoxical conclusions, for it can be shown by merely statistical reckonings that our notion that man passes through a period of development and a period of decline is misleading, in that in reality we begin with a period of extremely rapid decline, and then end life with a decline which is very slow and very slight. The period of most rapid decline is youth; the period of slowest decline is old age, and that this statement is correct I shall hope to prove to you with the aid of tables and lantern illustrations at the next lecture.

THE PLACE OF LINNÆUS IN THE UNFOLDING OF
SCIENCE; HIS VIEWS ON THE CLASS
MAMMALIA¹

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IN order rightly to appraise the value of Karl von Linné's contributions to biological science, it is necessary to bear in mind two very axiomatic facts. Our first axiom is that Linnæus became a point of departure in the history of modern biology only because he was in turn the product of the intersection of a great number of important causal series, which ramify and intertwine indefinitely and stretch back into the remote past of every aspect of life. The second axiom is that every new idea, or, for that matter, every new event, is the fertile hybrid from the fortuitous crossing of two or more specifically distinct old ideas, or events. And in order that we may discern a few of these fortuitous crossings and follow a little some of these interminable and intricate streams of cause and effect, it may not be inappropriate, in connection with the two-hundredth anniversary of the birth of Linnæus, to touch briefly upon a series of seven epochs of thought, from Aristotle to Darwin; and further to glance at the principles and facts upon which Linnæus based his two great contributions to the broader knowledge of the class of which man is the dominating member.

Not to go back indefinitely, we begin with the Aristotelian or initial analytic epoch of the fourth century B. C. Aristotle's theory of the genetic relationship of the chain of beings from polyp to man did not, of course, materially influence Linnæus. The idea of evolution which St. Thomas Aquinas, the "princeps scholasticorum" understood and developed, was not destined to come to its fruition through the schoolmen or even in Linnæus or Cuvier. But the true relation of Aristotle's thought to that of Ray and Linnæus may be exhibited in the following well-known citations from "The Parts of Animals."²

Some animals are viviparous, some oviparous, some vermiparous. The viviparous are such as man, and the horse, and all those animals which have hair; and of the aquatic animals, the whale kind, as the dolphin and cartilag-

¹This article is here published by courtesy of the council of the New York Academy of Sciences. It is largely adapted from a forthcoming memoir by the writer on the "History of the Classification of the Mammalia," prepared under the direction of Professor Henry Fairfield Osborn.

²Quoted by W. Whewell, "History of the Inductive Sciences," Svo, London, 1837, Vol. III., pp. 347.

inous fishes [in reference to the viviparity of certain sharks]. (Book I, chap. V.) Of quadrupeds which have blood and are viviparous, some are (as to their extremities) many-cloven, as the hands and feet of man. For some are many-toed, as the lion, the dog, the panther; some are bifid, and have hoofs instead of nails, as the sheep, the goat, the elephant, the hippotamus; and some have undivided feet, as the solid hoofed animals, the horse and ass. The swine kind share both characters. An allusion to the "mule footed" swine, monstrosities in which the median digits are fused and terminate in a solid composite hoof. (Book II., chap. V.)

Ray and later writers probably had this passage in mind when they used the descriptive terms "multifido," "bifido," "solidungula," "ungulata," "unguiculata," "fissipedes." Here also attention is directed to the feet as exhibiting characteristic differences.

Animals have also great differences in the teeth both when compared with each other and with man. For all quadrupeds which have blood and are viviparous have teeth. And in the first place some are ambidental³ (having teeth in both jaws); and some are not so, wanting the front teeth in the upper jaw. Some have neither front teeth nor horns, as the camel; some have tusks, as the boar; some have not. Some have serrated teeth,⁵ as the lion, the panther, the dog; some have the teeth unvaried,⁶ as the horse and the ox; for the animals which vary their cutting teeth have all serrated teeth. No animal has both tusks and horns; nor has any animal with serrated teeth either of those weapons. The greater part have the front teeth cutting, and those within broad (chap. II.).

This passage evidently directed the attention of later writers to the importance of the teeth as a means of distinguishing and hence of classifying mammals, and we shall see that Ray and, later, Linnaeus were quick to avail themselves of the suggestion.

Although Whewell⁷ proves that Aristotle was quite unconscious of the classification that has been ascribed to him, he also admits that "Aristotle does show, as far as could be done at his time, a perception of the need of groups, and of names of groups, in the study of the animal kingdom; and thus may justly be held up as the great figure in the 'Prelude to the Formation of Systems' which took place in more advanced scientific times."

Whewell quotes passages that show recognition of the lack of generic names to denominate natural groups. Aristotle says that "Of the class of viviparous quadrupeds there are many genera,⁸ but these again are without names, except specific names, such as man, lion, stag, horse, dog, and the like. Yet there is a genus of animals that have manes, as the horse, the ass, the *orcus*, the *ginnus*, the *innus*, and the animal which in Syria is called heminus (mule). . . . Wherefore," he

³ Αμφόδοντα.

⁴ Χανλιόδοντα.

⁵ Καρχαρόδοντα.

⁶ Δνεπάλλακτα.

⁷ *Op. cit.*, II., p. 350.

⁸ Είδη.

adds (that is, because we do not possess genera and generic names of this kind), "we must take the species separately and study the nature of each." "These passages," Whewell continues, "afford us sufficient ground for placing Aristotle at the head of those naturalists to whom the first views of the necessity of a zoological system are due" (*op cit.*, p. 352).

It is not necessary to dwell on the fact that from the time of Aristotle and his classical successors to the close of the middle ages Europe thought itself too much preoccupied to pay particular attention to natural history; on the one hand with world-wide displacements and readjustments of peoples and of institutions, and on the other hand with the development of the great body of religious and metaphysical doctrines. Even the next epoch requiring our attention, the scholastic epoch in the history of science, so far as natural history is concerned, is perhaps rather a further interregnum than an epoch, rather an era or lapse of uneventful time, than a time of the slow ascension of some great illuminative idea. The anthropocentric idea dominated in natural history as the geocentric idea dominated in astronomy and hence a knowledge of the real or supposed properties of animals, and especially of plants, was chiefly cultivated in connection with alchemy, magic, materia medica, etc. The medieval imagination, full of mysticism, eager for the uncanny and fantastic and teeming with images of the ubiquitous devils, flourished on the marvelous tales of a "Sir John Mandeville," and peopled the earth with the monsters which so long survived and ramped in the *Terræ Incognitæ* of world maps. In the schools citations from authorities were accepted in lieu of proof, and the simple zoology of Aristotle and the scriptures was deeply covered by the accretions of learned exegesis.

However, it must be remembered that scholasticism had reached its prime as far back as the thirteenth century, in the system of the illustrious St. Thomas Aquinas, and that while the renaissance movement was discovering new worlds in all directions, scholasticism in general (but with some brilliant exceptions) had reached the phylogerontic stage, and was producing all sorts of bizarre specializations in terminology and in dialectic.

Nevertheless, it can not be doubted that the very excesses of scholasticism stimulated the reactive return to experience, which gave rise incidentally to biological science. Furthermore, the schoolmen perpetuated and aroused interest in Aristotle's analyses, and gave currency to many methods of analysis and description. Among these we may cite the dichotomous method of division, which is a forerunner of modern classifications, and the logical concepts of genus and species. Especially noteworthy was the expansion of classical Latin into a highly specialized language of philosophy and science.

We now come to the renaissance epoch. Biological science, and especially zoology, did not respond fully to the impulse of the renaissance movement until literature, politics, astronomy and geographical discovery had made the most signal advances. Hence in Aldrovandi (1522–1605) and Gesner (1516–1565) the superstitions and myths of the middle ages still linger, while the systematic work of future generations is initiated in the extensive, illustrated catalogues and descriptions of plants and animals. On the philosophical side of zoology, the Englishman Wotton, in his “*De Differentiis Animalium*” (Paris, 1552,) “rejected the legendary and fantastic accretions [of medieval zoology] and returned to Aristotle and the observation of nature” (Lankester).⁹ One of the contemporaries of Gesner and Wotton was the founder of anatomy, Andreas Vesalius (1514–1564), who boldly broke with tradition and declared that the source of knowledge of the human body should be not Galen, but the human body itself.

Near the end of this period, the botanist, Cespino (Cæsalpinus), of Arezzo (1519–1778), himself a celebrated scholastic philosopher, but animated also by the new idea of direct observation, published his voluminous work “*De Plantis*” (1583). In this work the confused arrangements of plants of the earlier herbalists are replaced by an orderly classification suggested by the brigades of an army, and founded upon the number, the position and the figure of the reproductive parts. He divided plants into ten great classes, which were again subdivided; to these assemblages he gave monomial names in substantive form. Linnæus says of him that, “though the first in attempting to form natural orders he observed as many as the most successful later writers.” (Whewell, *op. cit.*, pp. 282–283.)

We may venture to suggest as a reason for this precocious development of a natural classification of plants the very multiplicity of kinds and the large herbaria and horticultural gardens in existence which necessitated some sort of orderly arrangement, and which would assist the eager student to recognize related series. We note in contrast the delayed progress of the classification of the mammals due to the comparative fewness of known forms, the greater complexity of organization and the difficulties of observation.

Among those who contributed the data for Linnæus’s generalizations, no name is more important, at least in the history of vertebrate zoology, than that of John Ray. Accordingly, the fourth epoch under consideration may be termed the Raian epoch, and culminates with the publication in 1693 of Ray’s “*Synopsis Methodica Animalium Quadrupedum et Serpentina Generis*,” which is one of the great landmarks in the history of classification. Ray’s debt to the past is shown in the

⁹ Lankester, E. Ray. *The History and Scope of Zoology*, in “*The Advancement of Science*,” London, 1890, p. 293.

facts that his very lucid tabular analyses of the common structural features of animals are arranged dichotomously, that in each division and subdivision a single adjective or adjectival phrase indicates the most important common feature of the animals in question, and that these terms are, as we have seen, in many cases borrowed from Aristotle.

Ray, like Linnæus, gave more attention to plants than to animals, and depended upon his colleague, Willughby, for much of the data, especially in the fishes. And, like Linnæus also, Ray had a superb gift of order and a philosophical mind that made him a worthy countryman and contemporary of Sir Isaac Newton.

In his tabular analysis Ray distinctly foreshadows Linnæus in the following points:

1. The higher vertebrates are contrasted with the fishes as breathing by lungs instead of gills.

2. The whales are classed with the viviparous animals and expressly removed from the fishes, from which they were further distinguished by the horizontality of the tail fin. This step, however, was felt to be so radical that Ray afterwards constructed a definition which included both whales and fishes.

3. As remarked by Gill, the terrestrial or quadruped mammals are bracketed with the aquatic as "Vivipara," and contrasted with the "Ovipara" or "Aves." "The Vivipara are exactly coextensive with Mammalia, but the word vivipara was used as an adjective and not as a noun. Linnæus did not catch up with this concept till 1758, when he advanced beyond it by recognizing the group as a class and giving it an apt name."¹⁰

4. The double ventricle is noted as characteristic of both Vivipara and Ovipara.

5. In order to associate the "Manati" and other amphibious mammals with their terrestrial congeners the term "hairy animals" is employed as more comprehensive than quadrupeds.

Ray further set the standard for Linnæus in his concise descriptions of European and foreign mammals, especially those described by travelers in America and in the east. Ray often used the term "species" merely as the equivalent of the middle English "spece," which survives in our word "spice," and meant "kind"; it was also equivalent to the logical "species (*cf.* the Greek *εἶδος*) of the schoolmen and is exemplified in Ray and Willughby's "Historia Piscium" in such phrases as "clarias niloticus Belonii mustelæ fluviatilis." "bagre piscis barbati ac aculeati species." But Ray also used the term species in quite a Linnæan manner, as in the names *Ovis laticauda*, *Ovis strepsiceros*, *Ovis domestica*, etc. In form, at least, this foreshadows the binomial sys-

¹⁰ "The Story of a Word—Mammal," POPULAR SCIENCE MONTHLY, Vol. LXI., September, 1902, pp. 434-438.

tem of nomenclature and the recognition of the species in general as an objective reality and the unit of classification. But the form of Ray's specific definitions seems to imply that the term "species" in Ray's mind was often more a "differentia," or specific adjective modifying the generic concept, than a fully-developed substantive name, and Ray did not apparently realize the convenience of applying the binomial method of nomenclature universally. Even Linnæus at first introduced the specific, "trivial," or common, name, merely as a marginal index or symbol of the full specific phrase. Ray recognized the considerable variability of species but believed also in their separate creation and fixity. Ray frequently adverts to the internal characters of animals, and even a cursory examination of his book shows that, even by his time, a considerable number of observations on the soft parts of animals had already accumulated.

The work of Ray in botany and zoology fully prepared the way for Linnæus himself, whose epoch may be designated as the Linnæan or legislative epoch, because in his time methods of description, of classification and laws of nomenclature became fully established and settled. Linnæus inherited from Ray and from the scholastic system, the dogma of the separate creation and objective reality of species which became developed and strengthened in his hands as a result of his observations. His dictum was "species tot sunt diversæ quot diversæ formæ ab initio sunt creatæ." The resemblance between members of a single species were hence held to be due to descent from an original pair, and the mutual infertility of species to be the natural penalty of the effort to traverse the gaps established from the beginning.

And now that we have traced briefly the steps leading up to Linnæus, a few words more will summarize the relation of Linnæus to his successors. The sixth epoch in the history of zoology extends from the latter part of the eighteenth to the middle of the nineteenth century, and may be called the anatomical epoch, because, through the labors of Cuvier and his great English pupil and successor, Richard Owen, the taxonomic studies of the Linnæan school were supplemented by the establishment and great development of the sciences of comparative anatomy and paleontology. Cuvier's researches in these sciences further extended the dogma of the fixity of species, but Owen, through his broader knowledge, gradually gave up the idea and became an evolutionist, although not a selectionist. The seventh epoch, the Darwinian, in which happily we are living, has seen the overthrow of the traditional doctrine of the fixity of species, and has initiated the reexamination of all cosmical and terrestrial phenomena in the light of the doctrine of evolution.

Thus the great lawgiver of natural history is seen in his proper perspective, inheriting, on the one hand, the language and

general methods of the past and the doctrine of special creation; inheriting, on the other hand, the new spirit and contributions of Vesalius, Cesalpino, Ray and many others, and building upon this the foundations of modern botany and zoology.

In attempting to appraise Linnæus's contributions to the broader knowledge of the class of mammals, we must bear in mind what Dr. J. A. Allen has well shown, namely, that Linnæus was primarily a botanist, that his interest in mammals was incidental, his opportunities for studying them very limited and his first-hand knowledge of extra-European mammals practically *nil*; and finally that several of his ordinal groupings of mammals (*e. g.*, rhinoceros with the rodents) now appear highly unnatural and even ludicrous. But there are certain considerations which may prevent us from thinking any the less of Linnæus's judgment and genius on that account.

Although Linnæus may have known very little about extra-European mammals, he had, nevertheless, a fairly good conception of the essential features of mammals as a class, as shown by his definition in the tenth edition of the "Systema Naturæ" (1758). Here in concise phrase he states that mammals have a heart with two auricles and two ventricles, with hot red blood, that the lungs breathe rhythmically, that the jaws are slung as in other vertebrates, but "covered," *i. e.*, with flesh, as opposed to the "naked" jaws of birds; that the penis is intro-mittent, the females viviparous, that they secrete and give milk, that the channels of perception are the tongue, nose, eyes, ears and the sense of touch: that the integument is provided with hairs, which are sparse in tropical and very few in aquatic mammals; that the body is supported on four feet, save in the aquatic forms, in which the hind limbs are said to be coalesced into a tail (the only erroneous idea in the whole definition).

Many of these characters had previously been noticed by Ray in his description of the hairy quadrupeds; and it is not impossible that Linnæus may have been assisted to the comprehension of the essential features of the mammals through his friendship with Bernard de Jussieu, who is said by Isidore Geoffroy St. Hilaire to have induced him to include the Cetaceans in the class Mammalia; and possibly he owed something to the researches of Klein and Brisson. But Linnæus's own studies in medicine, in Holland, doubtless made him familiar with the anatomy of at least one mammal, man, and on his journeys through the north of Europe he must have observed many mammals at close range.

All this prepared him for the clear recognition and emphasis of two facts of far-reaching importance. It was evidently well known

that the anatomy of mammals was similar in plan, if not in detail, to that of man, and we find Descartes, for example, in his "Discourse on Method" (Part V., 1637) advising those who wished to understand his theory of the action of the lungs and circulatory system, "to take the trouble of getting dissected in their presence the heart of some large animal possessed of lungs, *for this is throughout sufficiently like the human*" (*ital. mihi*). And it was further known that of all animals the monkeys are most nearly like man, both externally and internally. This was asserted by Aristotle and other classical authors but was fully demonstrated in a carefully prepared and illustrated work¹¹ on the anatomy and appearance of animals from the Jardin du Roi, by a committee of savants of the French Academy, appointed by the Grand Monarch.

That this work and these important facts came under the notice of Linnæus on the occasion of his visit to Paris in 1738 is not improbable. At any rate, Linnæus did not hesitate to follow the logical consequences of these facts, namely, that in a strictly zoological classification man would be grouped not only in the class mammalia, but even in the same ordinal division with the monkeys. Accordingly, in the tenth edition of the "Systema" the earlier name Anthropomorphæ is replaced by Primates, and the genera *Homo*, *Simia*, *Lemur*, *Vespertilio* are grouped under that order. The Primates were thus regarded as the chiefs of the graded hierarchy of terrestrial beings, and consequently, as in nearly all subsequent schemes down to the Darwinian epoch, head the classified legions of creatures. This allocation of man to the order Primates was surely an instance of Linnæus's genius in surmising the true affinities of puzzling organisms, and led the way to the modern generalization that man is knit by ties of blood kinship to the Primates, and more remotely to the whole organic world.

The diagnostic definition given by Linnæus of the order Primates may be cited because it rests upon the principles and theories which guided him in classification and which led to his most successful groupings, as well as to his serious blunders. This definition is as follows:

Inferior front teeth iv, parallel, lanariform [canine] teeth solitary [*i. e.*, in a single pair].

Mammæ pectoral, one pair.

The anterior extremities are hands.

The arms are separated by clavicles, the gait usually on all fours ("incessu tetrapodo volgo").

They climb trees and pluck the fruits thereof.

That this definition was insufficient to exclude all extraneous genera from this really natural order is evident from the facts: (1) That under

¹¹ "Mémoires pour servir à l'Histoire naturelle des Animaux." à la Haye, 1715 (4to, 2 vols.), Rédigées par Perrault et Dodart.

Lemur Linnæus included not only all the then known forms now recognized as the suborder Lemuroidea, but also the "Flying Lemur" *Galeopithecus*, which properly either forms an order by itself with no near affinities with the Primates, or is at most a suborder of the Cheiroptera. (2) The definition also included the bats (*Vespertilio*), an order more nearly related to the Insectivores than to the Primates.

Many of the characters selected by Linnæus for his ordinal diagnoses were of the "adaptive" or superficial kind which are now known to have been most easily modifiable by changes in the external or internal environment. The reason for this mistake (a mistake from which few naturalists were free even down to our own generation) was that Linnæus regarded the mode of sustenance of a group as one of its most deep-seated attributes, most surely indicative of more or less hidden affinities with other groups. For it is well known that Linnæus was constantly searching for natural groups, although he did not realize that the natural affinity of the members of the larger groups was due to descent from common ancestors, just as in the case of members of the same species. An example of his reliance upon sustenance is seen in his definition, in the tenth edition of the "Systema," of the order Feræ, the Carnivora of later authors. Here "sustenance by rapine, upon carcasses ravenously snatched" is evidently felt to be connected with "front teeth in both jaws: superior vi, all acute," with "laniariform teeth [canines] solitary," with "claws on the feet acute." But one of his dicta in botany was that a character of great systematic importance in one group may be very variable in another, consequently he did not mention sustenance under Bruta, but contented himself with the two characters "front teeth none either above or below" and "gait awkward (*incessus ineptior*)." As this order included the elephant, the manatee, the sloth, the great anteater and the scaly anteater, it has been justly cited as a grossly unnatural assemblage; and the grouping accounted for by Linnæus's ignorance of the animals composing it. But I am more disposed to attribute it first to his habit of searching for hidden affinities below the most obvious external differences, as when he placed the seals in the order Feræ, joined the bats with the Primates, the horse and the hippopotamus, the rhinoceros with the Rodents, and the pig with the Insectivores (in the order Bestiæ). That Linnæus recognized that the ordinal classification of the mammals was a difficult problem is shown by the conspicuous changes (not always improvements in our eyes) and redistributions which he made between the first and "tenth" editions of the "Systema" and further by the fact that Erxleben who revised and extended the Systema (1777) abandoned the ordinal divisions entirely and merely listed the genera seriatim. The difficulty of the problem in indi-

cated by the fact that Cuvier, with far better material and more extensive knowledge, was constantly deceived by "adaptive" (or homoplastic) resemblances, and that even Professor Cope, who wrote much on homoplastic and convergent evolution, was himself deceived by the similarities of structure in the Marsupial "mole," *Notoryctes*, and the Cape Golden mole (*Chrysochloris*), an undoubted Insectivore. Furthermore, that even the most "inexcusable" blunder of Linnæus, that of placing rhinoceros with the Rodents under the order "Glires," was due, not to carelessness, but to the fact that the Indian rhinoceros has a single pair of close-set cutting incisors in the upper jaw which oppose the elongate incisor-like appressed canines of the lower jaw, and thus show a superficial approach to the Rodent dentition. If Linnæus had known that *Hyrax*, which Pallas described as a Rodent ("Cavia"), had cheek teeth like those of *Rhinoceros*, he doubtless might have felicitated himself upon his supposed astuteness.

In brief, Linnæus (as fully shown by Whewell¹²) from his profound and wide botanical knowledge, was acquainted with many natural orders and strove constantly to recognize others; he knew that a character of great diagnostic and fundamental value in one order may be of slight value in another; he knew that even in a natural order some of the diagnostic and fundamental characters might be absent in certain members otherwise clearly allied to a given series. He knew that a natural series is natural because of the totality of its characters, that the "genus makes the character" and not *vice versa*—a hard doctrine to many of his contemporaries. And when he had arrived at a conception of any given natural order he selected certain characters as diagnostic but not necessarily universal, and constructed professedly artificial or only partially natural keys to his "natural" orders.

Thus we may believe that when Linnæus turned his attention to the classification of animals he followed the same principles. And in this application of the principles gained in one subject to the data of another, we have a good example of the felicitous union of specifically distinct ideas to produce a line of ideas that were new and very fertile.

¹² *Op. cit.*, pp. 319-325.

RECENT LEGISLATION ON THE MISSISSIPPI RIVER

BY ROBERT MARSHALL BROWN

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THE new River and Harbor Bill is of particular interest in the portion pertaining to the Mississippi River. For over twenty years levee construction and maintenance has been the dominant feature of the river's regulation. During nearly half that time a concerted effort has been made to maintain a navigable channel when the river is at a low stage. There are indications that the catchword for the years to come will have reference to a 14-foot waterway from the lakes to the gulf. In the original act¹ three lines of procedure, one a continuation of former projects, the other two in some wise new projects, were advocated. Briefly, these are as follows:

1. An appropriation for the general improvement of the river, for the extension of the levee system and for the improvement of navigation. This includes the maintenance of a navigable channel of at least 200 feet in width and 9 feet in depth from Cairo to the Gulf.

2. An appropriation for the improvement of the river from the mouth of the Ohio River to the mouth of the Missouri River. This appropriation is a reduction of the sum appropriated in the last River and Harbor Bill.

3. The appointment of a board to report upon the practicability and desirability of constructing a navigable channel 14 feet deep and of suitable width from St. Louis to the Gulf, either by improvement of the river or by a canal or canals for a part of the route.

The first of these continues the work under the control of the Mississippi River Commission, a board created in 1879. This board has defined the law which created them in the following general terms:²

1. Continuation of surveys; preparation and publication of maps, maintenance of gauges; the recording, tabulating and publication of gauge readings; the taking and recording of discharge measurements at high and low stages of the Mississippi River and its tributaries, and other observations.

2. The building, extension and repair of levees.

3. The building, maintenance and operation of dredge boats.

4. The repair and extension of existing works for the improvement of the channel, the preservation of harbors, the prevention of cut-offs, and the security of levees.

5. The maintenance of a low-water channel between the Mississippi, Red and Atchafalaya Rivers.

¹ H. R. 24991. An act making appropriations for the construction, repair and preservation of certain public works on rivers and harbors and for other purposes.

² Report of the Mississippi River Commission for the fiscal year ending June 30, 1906, p. 2470.

Although the history of the confinement of this river covers a period of nearly 200 years, no concerted plan for the regulation of the river in its extent through the alluvial basin had been attempted. The commission took up its work at a peculiarly fortunate time. The organization was about completed when, in 1882, a flood of unprecedented size overflowed the whole alluvial basin and destroyed most of the levees then existing. The slate was clean. No previous work conceived along narrow lines blocked the progress of any project which the commission might formulate. The land owners and riparian proprietors were discouraged. Their work in levees was destroyed and burdensome taxes for levee construction had profited them little. The allotments of money appropriated by the government revived their spirits and renewed efforts were instituted. Levee construction has gone on continuously from that time to the present, until to-day a little less than 75 per cent. of the banks of the river south of Cape Girardeau, Mo. is leveed. The recommendations of the commission show that the early completion of the system of levees is in their opinion a desideratum. The levees have been constantly increased in height. This was expected. The confinement of waters within narrower and narrower limits as the levees increased in length would be evidenced in the vertical expansion of the waters. There is no criterion for the height of the embankments except the highest known stage of the river. It is planned to exceed this stage by from 2 to 4 feet. The difficulties of this arrangement may be illustrated by the floods of 1897 and 1903. A provisional grade 2 feet above the 1897 flood was adopted; in 1903 the flood was in some places 2.5 feet above the 1897 stage and the waters would have over-topped the levees had they not been reenforced by sand bags. After the 1903 flood a new provisional grade was adopted which in some instances is 5 feet above the provisional grade for the years before. There always remains the possibility, and it is not a remote one, that the highest-known flood may be exceeded in stage.

That the constructions and vigilance of the men working under this commission have been effective, the showing of the Yazoo Basin proves. This basin, having an area of about 6,300 square miles, equivalent to the combined areas of Connecticut and Rhode Island, has in twenty years experienced an increase of over 100 per cent. in its population. In 1900, 195,346 people were living in this area. Railroads have been built, forests have been removed, lands cultivated, industries of many kinds developed and holdings of scarcely a nominal price have become farms of considerable value.

That protection has not always been accorded the dwellers of this and other basins is also evident when the records of flood seasons are reviewed. In the Yazoo Basin during the high water of 1903, the last high water season, one fourth of the basin was under water; one half of the city of Greenville inundated; 60,000 people, or one third of the inhabitants of the basin, driven from their homes, and traffic was sus-

pended on the railroads, on the Yazoo and Mississippi Valley Railroad for twenty days and on the Riverside Division for forty days. There was no loss of life or of live stock and most of the movable farm implements and machinery were saved. For this protection from loss a great share of the credit should be given to the Weather Bureau, which sent out warnings to the inhabitants of the basin a few days before the river reached its highest stage.

Another line of work in charge of the commission is the maintenance of a navigable highway from Cairo to the Gulf. The specifications demand a channel of at least 200 feet in width and 9 feet in depth. To meet this demand, a number of dredges have been constructed, and as fast as the river falls in stage and approaches a 9-foot depth dredging operations are inaugurated. It has been proved that, unless the river falls to an abnormally low stage, it is altogether within the power of the dredging parties to maintain the required size of channel. Notwithstanding this surety and this success, the traffic of the river has declined in volume during the last thirty years. This decline may be due to a number of causes. The greater length of the waterway over the railway between the same ports resulting from the meandering of the river, and the greater speed attainable in rail traffic make the time by rail to the time by water from St. Louis to New Orleans as 1 to 10. A second disadvantage of the water route lies in its uncertainty. During high water stages navigation is difficult. At times the boats are ordered to go at slow speed lest the wash increase the caving of the levees. There is also an uncertainty concerning the location of the low-water channel. Even with the success of the dredging operations the channels are often difficult and hard to run. A third cause which is emphasized by the loss of time and the uncertainty of the passage is the constantly decreasing difference between the tariffs by rail and by water. A fourth cause lies in the active part which railroad companies have taken in the competition.

A liberal appropriation is made for the continuance of the work of the parties under the direction of the River Commission. While different judgments concerning the efficiency of their work prevail, the opinion is a general one that this work ought to be prosecuted until a more obvious means of benefiting the people of the alluvial basin and at the same time serving the needs of the inhabitants of the valley can be devised.

The second point in the River and Harbor Bill was an appropriation of \$250,000 for the stretch of river between the mouth of the Missouri and the mouth of the Ohio. The Senate amendment to this portion of the bill was a complete renovation with an appropriation of \$650,000. It was later understood, however, that the Senate conferees had yielded to the argument of the House conferees and would allow the amendment to be stricken from the bill. During the four seasons just past this stretch of river has had an appropriation of \$650,000 annually. In

1897, the appropriation was \$673,000; in 1903, \$758,000. The debate upon this reduction was long and brought out some interesting statements. The reasons for this reduction may be summed up as follows:

1. There has been a continual falling off in the traffic along this stretch of river. While the projected 8-foot channel has to a large degree been maintained, at no time has the improvement of this portion of the river been reflected in the traffic. Altogether there has been spent on this portion \$12,000,000, and the traffic last year was only about 440,000 tons. This tonnage of traffic does not include ferriage, which is little affected by river improvements.

This loss of traffic was explained by the citation of conditions which are similar in the Kansas-St. Louis stretch of the Missouri River. When the boats began to get the business between these two cities, the railroads paralleling the river organized a determined opposition. The roads acted concertedly and reduced the tariff rates along this stretch of river to one third the former scheduled rates. They were reported to have gone even further. They went out and under-bid the boats. Gradually the stock in the boat lines passed from the hands of the promoters, and competition ceased. The old schedule of railroad rates was then resumed. It is also suspected that the rebate system until recently in vogue between large shippers of freight and the railroad companies acted against the river traffic. Along the Cairo-St. Louis stretch of the river, the building of boats ceased in 1893, and a constant reduction of the fleet has gone on since that date.

From	To Memphis			To New Orleans			To St. Louis	
	A	B	C	A	B	C	A	C
Clarkestale	76.7	\$1.25	\$0.56	378.9	\$2.25	\$0.72	390.1	\$1.21
Friars Point*	70.1	1.00	.45	385.5	1.00	.45	383.5	.90
Cleveland	113.6	2.00	.62	342.0	—	—	—	—
Rosedale*	114.0	1.25	.45	341.6	—	—	—	—

* On Mississippi River.

A, distance in miles; B, cotton per bale; C, first-class merchandise per 100 pounds.

It is claimed, however, in rebuttal that it is immaterial whether the tonnage is actually floated on the river or not. The means of cheap transportation is gained if the riverway is open to traffic. Two illustrations of this follow. It is about the same distance from St. Louis to three Mississippi towns, Greenville on the Mississippi River, Greenwood on the Yazoo River and Winona, inland. The freight rates by rail to these towns are, to Greenville, \$0.90 per one hundred pounds, to Greenwood, \$0.96, and to Winona, \$1.14. In other words, the improvement of the river from St. Louis to Greenville and to Greenwood has accomplished the ends desired, even though the transportation has to a large extent been by rail. A still clearer case is made out in the preceding table.³

2. The engineers have not agreed concerning the works along this stretch of river. They have been at "loggerheads." Furthermore they could not spend the annual appropriation of \$650,000. At the end of the fiscal year in 1905 it was reported that there was a balance on hand of \$915,000.

3. The proposition of a deep waterway (14 feet) from Chicago to New Orleans *via* this stretch of river affected the appropriation. If this 14-foot waterway is attempted it seems to be the feeling that the depth in some portions, if not all, of this stretch of river between St. Louis and Cairo would have to be obtained by a lateral canal. It was not prudent to allot money for permanent improvements as long as a change of policy was imminent. It is claimed that the reduction of the appropriation is not hostile to this portion of the river nor to the proposed 14-foot waterway. It is a temporary halting of work in order to await the development of other projects and to give the engineers time to study the problems further in the hope of a closer approach to unity of recommendation.

The third section of the River and Harbor Bill pertaining to the Mississippi River had reference to very extensive improvements of the river and had for its main clause the consideration of a 14-foot waterway from St. Louis to the Gulf. The realization of such a waterway with the completion of the project, already instituted, of a 14-foot waterway from Chicago to St. Louis will give a deep waterway from the sea to the Great Lakes. There is little opposition to such an undertaking. It is generally admitted that a highway of this nature would prove of great value to the country as a whole. The immediate need of this waterway arises from the fact that the products of the valley have outstripped the carrying capacity of the railroads. It has been admitted by railroad men that there is no promise of greater transportation facilities, and that the construction of new lines, of new cars and engines, can not keep pace with the increasing output of mills, plains, forests and mines. The only relief to this congestion seems to lie in the Mississippi River. The regulation of this stream up to the present day has not been of such a nature as to greatly benefit the producers and give them a highway for their output.

While it is generally conceded that all this is true, the proposition for the regulation of the river has been accompanied by plans of so visionary a nature that many people have withdrawn for a season their support or have cast their lines in opposition. This section of the River and Harbor Bill carried with it no feature to which objection should be taken. It plans for a thorough inspection of the problem of a deep waterway by a competent committee. This committee is directed to report to congress on the feasibility of such a waterway. Its duty is one of investigation, not of operation. We may expect a careful consideration of all the problems pertaining to a deep waterway and such recommendations as they see fit to make. There is in the specifica-

tions drawn up for this committee a clause which requires them to report upon the possibility of using locks and dams similar to those in use on the Ohio; in other words, to ascertain whether the canalization project is feasible for the Mississippi River. It is this project of canalization which has aroused opposition. Some of the proposers of this plan of improvement, and they were probably the instigators of this section of the bill, have advocated canalization as the only means of obtaining the requisite depth of channel. It is but just to assume that the business men of the valley, and especially the St. Louis contingent, have a definite and well-considered plan for gaining a deeper waterway. At the same time it is unfortunate that their desires should have been introduced to the general public as an undertaking of stupendous magnitude and a work which the public would be forced to promote. An extravagant speech in congress which pictured the bounds of a canalization plant as "two granite walls, 200 feet high and 2,000 miles long" in comparison with which the Chinese wall "7 feet high and only about 450 miles long" is diminutive, was probably no more excessive than the terms by which the speaker may have been informed of the project.

The canalization of a river is not a new method of benefiting the navigable quality of a river. Many streams in Europe, as the Elbe, Seine and the Main, and some streams in this country, portions of the Ohio, for example, have been regulated successfully by this method. The canalization of a stream turns the river into a series of steps; passage from one step to the next higher or lower is made through a lock, and the height of water is sustained by a dam across the main channel of the river. The stream-flow is thus blocked and navigation is as easy up-stream as down. The best arrangement of dam and lock is possible when an island divides the stream into a main channel and a chute. If the dam or weir is located in the main channel and the lock in the secondary channel, high-water stages are not as likely to impair the locks. The weir, however, must be made movable so as not to oppose the flood force. This, in brief, is the process of canalization. While the projectors of this plan for the Mississippi River have not definitely stated what type of canalization plant they advocate, there are certain features which above others must enter into the consideration of every project of a serious nature. A few of the most salient of the characteristics I desire to mention, and, without taking issue with the promoters of canalization, to point out, here and there, the probable effects of these on canalization works.

The discharge of the river is enormous. The potent factors in river discharges are the precipitation of rain over its basin and the porosity of the soil of the basin. The Mississippi River system drains about one third of the United States. The annual discharge of the river is greater than the combined annual discharges of the Po, Danube and the Rhone. This body of water fluctuates in its flow from a flood stage in the spring to a low-water stage in the autumn. The difference in height between

these stages is commonly 50 feet. Any works in the river must be strong enough to withstand the enormous body of water of the flood stage. The locks in the chutes or side channels within the highwater levees will be inundated. The movement of the water must cause scour; and weirs, locks and abutments leading thereto would be threatened with imminent destruction.

The ratio of sediment carried by the river to the stream discharge is large. Much of this sediment is rolled along the bed of the river in waves transverse to the direction of stream flow. It is estimated that the total amount of sediment yielded to the Gulf yearly is a little over 400,000,000 tons. Enormous quantities of sediment find a temporary lodging place during the low-water season along the bed of the river. It is because of this sediment that the present dredging project is extant. It is admitted by the enthusiasts for canalization that the sediment would be injurious to a canal plant. They offer as a remedy the removal of the sediment by catchment basins before the navigable portions of the river are reached, or the removal of the sediment from the tributaries by some similar process, or the retention of the 400,000,000 tons of sediment "in the townships where it belongs." Any one of the remedies mentioned means a task as great if not greater than the original project. Catchment basins are easily constructed in small streams, but to suggest such a thing for large streams with a variable flow, the Cumberland and Tennessee Rivers for example, is to gamble with success. The retention of the sediment "in the townships where it belongs" is visionary. Some of the sediment comes from the caving banks of the river itself. This could not be eliminated. Furthermore, if the stream is deprived of much of its sediment, the power which ordinarily is expended in carrying its load can then be spent in further scour of its banks. Thus, to some degree, the deprivation of sediment will work to the harm of the protective levees.

A flood often falls rapidly in stage. During a sudden drop, the waters dump quantities of detritus along the bed. If we deny that during flood stages the sediment can be removed from the tributary streams, we must have fear for the effect of the sudden falls in river stage. Because of the resistance offered by any construction in the flooded stream, sand would tend to accumulate about such works. It is subsequent to these sudden falls that the dredging corps has to exert its utmost power in order to maintain the nine-foot depth of the dredging project. The removal of the sand from the wiers and locks would not necessarily last throughout the low-water season. Oftentimes secondary rises of the river occur which move the sand waves down-stream and obscure the trace of any previous work in dredging. Canalization, furthermore, would not make unnecessary the dredging plant. It is likely that as large a plant would be required. Dredging is carried on in the canalized rivers of Europe.

The river is long and tortuous. It has a width varying from one-

half mile to a mile. The distance from Cairo to the sea is about 600 miles; there are over 1,700 miles of river in this distance. A meander of the river adds from twelve to twenty-five miles to the length of the river, with but a mile or two of gain in distance towards the sea. The current of the river is directed alternately against the banks of the stream. Scour and caving result and sediment is added to the river. The change of locality of the river current thus engendered must be stopped in order to make the expensive canalization works other than temporary constructions. To stop this scour, dirt levees and brush revetments will not suffice. It means more solid walls on both sides of a very long river. It means an enormous appropriation and years of labor. The width of the river will add to the item of expense. A thoughtful person would deliberate and weigh carefully all the factors bearing upon the problem before advocating such an expenditure as this plan contemplates, even if he were absolutely sure of the ultimate success of it; and success in this canalization project, from our present knowledge, is not so to be rated.

It is comforting to know that procedure in this enterprise is to be slow, and that there will be time and money for a detailed study of the problem, and an opportunity for a thorough consideration of the report of the investigating committee before the country is harnessed to any definite system of regulation. There may be a call for haste as far as the immediate needs of the people of the valley are concerned. However, whatever system is inaugurated can only be begun to-day, will take years for the fulfillment and should endure for a long time. We have the assurance, furthermore, of a thorough agitation of the whole inland waterway question. In compliance with the request of numerous commercial organizations of the Mississippi Valley, the President has appointed an Inland Waterways Commission. This commission is directed to investigate the problems of inland waterways and to report with recommendations upon the problems relating thereto.

There is in the present River and Harbor Bill, in the portion relating to the Mississippi River, and in the appointment by the President a promise that the United States has instituted a more comprehensive plan than has up to this time been possible. Much of the debate on the River and Harbor Bill had back of it the sectional spirit, the demands of a locality upon its representative in congress. There is room for a larger view of river regulation than the satisfying of constituents; and the new Inland Waterways Commission can gain for us no greater boon than to infuse the states with the spirit of cooperation in place of that of rivalry.

THE DEVELOPMENT OF TELEPHONE SERVICE

BY FRED DELAND

PITTSBURGH, PA

XIII. THE PARENT BELL COMPANIES

IT will be recalled that in the circular announcement sent out early in May, 1877, the essential text of which was reproduced in Chapter IV., the owners of the Bell patents style themselves 'the proprietors of the telephone.' These 'proprietors' in the beginning were Alexander Graham Bell, of Boston; Gardiner Greene Hubbard, of Cambridge, and Thomas Sanders, of Haverhill, each of whom held a one third interest. Then these gentlemen arranged to secure the services of Thomas A. Watson, who as a young mechanic and electrician in the Williams' shop had assisted in many of the early experiments, had made some of the early telegraph and telephone apparatus, and was familiar with Graham Bell's hopes and plans concerning the transmission of speech. In return for devoting all his time to the promotion of telephone interests, Mr. Watson received in lieu of cash payments a one tenth interest in the Bell patents. This reimbursement for services to be rendered had little tangible value at that time, but three years later could easily have been sold for more than a hundred thousand dollars. Under this arrangement Bell, Hubbard and Sanders each held a three tenths interest and Watson held one tenth.

The appearance of that first telephone circular combined with the appointment of active special agents, working on a liberal commission basis, gradually created a demand for telephones for use on private lines and for experimental purposes, and it soon became evident that quite a sum of money would have to be expended in manufacturing and delivering these instruments. But so little faith had capitalists in the future of the telephone, that it is said that Mr. Hubbard found it very difficult to raise sufficient funds to float the telephone. Thus, with a view to simplifying the conditions under which the necessary funds could be secured and the interests of the proprietors protected, on July 9, 1877, Mr. Hubbard was made trustee of the patents and empowered to exploit them for the best interests of all concerned. In turn he formed an association or partnership arrangement, "for the purpose of manufacturing and introducing said telephones into general use throughout the United States." This association was composed of only seven members during its entire life, and its affairs were managed in behalf of these seven beneficiaries by officials of their selec-

tion. The title of the organization was the Bell Telephone Association; it was not incorporated and had no capital stock, but on August 1, 1877, beneficiary certificates were issued as follows:

Gardiner Greene Hubbard	1,387	shares.
Gertrude Hubbard (Mr. H.'s daughter)	100	"
Charles Eustis Hubbard (Mr. H.'s brother)	10	"
Alexander Graham Bell	10	"
Mabel Hubbard (Mrs. A. G.) Bell	1,497	"
Thomas Sanders	1,497	"
Thomas A. Watson	499	"
Total	5,000	shares.

The active career of the association dates from August 1; Mr. Hubbard served as trustee, Mr. Sanders as treasurer, Mr. Watson as electrician, and an office was opened in room 13 in the Sears building in Boston.

Two days after the patents and property had been assigned to Mr. Hubbard as trustee, that is on Wednesday, July 11, 1877, Graham Bell and Mabel Hubbard were united in marriage at the home of her parents in Cambridge, and his wedding gift to his beautiful bride was his entire three tenths interest in the telephone patents. Thus it was to Mrs. Bell that the certificates of the association and the shares of the parent company's stock were issued when those incorporated bodies were organized and when they gave stock certificates in exchange for certificates previously issued.

Shortly after the wedding the bridal couple left for England and a tour on the Continent and did not return to this country until August, 1878. In London on October 31, 1877, Graham Bell delivered his often-quoted lecture before the Society of Telegraph Engineers, in which he detailed the researches made by himself and many others in the effort to solve the problem of telephonic transmission of sounds and speech, beginning with those of Dr. Page in 1837.

From the date of his departure to England, Graham Bell was in no way connected with the exploiting or the financing or the management of the telephone in the United States. He was the consulting electrician of the early companies, and earnestly strove to solve the technical problems brought to his notice. But while he held very liberal views on the question of local organization, he did not believe in cheap construction, nor in the use of temporary expedients that could only bring the system into disrepute and hamper and delay the introduction of good telephone service.

As already stated, following the organization of the Bell Telephone Association, the exploitation of the telephone was systematically pushed throughout the United States. This involved far greater labor and outlay than would now seem necessary to introduce so valuable a public utility. For the openly expressed skepticism of capital had to be overcome, the groundwork of a new industry had to be laid, plans for the

granting of territorial rights under equitable conditions had to be formulated, methods had to be devised for the establishment of central telephone exchanges, then equitable conditions planned for connecting neighboring exchanges with toll lines, and, finally, the invention of accessory telephone equipment and its economical manufacture and reasonable marketing. To-day there are many who believe they can tell far better how to plan these things than the parent Bell is now doing. But in the pioneer days there was no wealth in the treasury or in prospect, and there were none who were competent to advise intelligently on technical telephone questions, or to share practical telephone experience, while there were many very intelligent men who did not hesitate to discourage the movement in every way; for they could not perceive how speech transmission could have any commercial value. Yet, notwithstanding all these discouraging conditions, a careful study of the plans under which licenses were granted for operating exchanges and for toll lines interconnecting exchanges, shows a far-sighted conception of the ultimate growth and interrelation of exchanges that wins heartiest admiration.

Mr. Hubbard made many visits to various cities and endeavored to interest capital in the new invention, and he loaned telephones to men of influence in the hope that daily use would lead them to perceive the future value of the invention. But scarcely one of the men, who should have foreseen the growth of the telephone industry and who might have assisted in establishing it under favorable conditions, gave him any encouragement. So he was compelled to turn to men who had little money, but much energy combined with a strong faith in their own abilities to succeed. Thus, as a rule, it was men of this type, rather than the financier, who helped to lay the foundations of exchange telephone service in many localities.

In the beginning the parent company had seriously considered the advisability of forming a second organization to build, equip and operate telephone exchanges in all our cities. Though this plan was strongly advocated by men whose faith in the greatness of Alexander Graham Bell's invention and in the ultimate success of the telephone had never faltered, four good and sufficient reasons soon showed how impracticable it would be to carry the plan through on a satisfactory basis:

First. The more the plan was analyzed the greater appeared the actual cash investment that would be required to establish exchanges in all the cities in the United States, until the total amount that would be required aggregated more than a hundred millions, a sum almost fabulous in 1877, yet actually necessary if this new and untried industry was to be properly built up.

Second. For one company to undertake to build exchanges in all

the cities in the United States, and interconnect the same with toll lines, would necessarily involve much delay in building, and compel many communities to wait several years before receiving telephone service.

Third. The absence on the part of capitalists of faith in the intrinsic value of this incomparable invention precluded the possibility of financing any large telephone exchange system embracing the principal cities in one state only, to say nothing of a proposition of such magnitude as to include the leading cities throughout the country.

Fourth. Local interest supported by local investments was absolutely essential to insure even the small growth that was then considered satisfactory.

How great this lack of faith was, and how often Alexander Graham Bell, Gardiner Greene Hubbard and Thomas Sanders and their early associates met with rebuffs when inviting capital to join with them in promoting the establishment of telephone exchanges in 1877, and how widely capitalists were misled into believing that the telephone had 'no commercial value,' by the very men who should have been the first to grasp the possibilities in so revolutionizing an invention, may be shown in two quotations.

In November, 1876, after Sir William Thomson's glowing description of the successful telephone experiments at the Centennial had aroused the interest of scientists everywhere, a prominent electrician, who later claimed to have invented the telephone, wrote to his attorney on November 1, 1877:

As to Bell's talking telegraph, it only creates interest in scientific circles, and as a scientific toy it is beautiful, but of no commercial value. We can already do more with a wire in a given time than by talking, so its commercial value will be limited.

And the editor of *Engineering*, of London, then the leading engineering publication of the world, in calling attention to 'the extreme simplicity of receiver and transmitter,' stated in the issue of December 12, 1876, that the instruments were

so simple indeed that were it not for the high authority of Sir William Thomson, one might be pardoned at entertaining some doubts of their capability of producing such marvelous results.

Only those familiar with the situation can realize how great and how unreasoning was this lack of faith on the part, not only of capital, but of scientists, mechanics, merchants. But here is an excerpt from an editorial written at the close of 1883, by a journalist thoroughly conversant with the telephone situation from the beginning:

The issuance of Bell's patent, on March 7, 1876, attracted little or no attention in the telegraphic world. The inventor was practically unknown in electrical circles, and his invention was looked upon, if indeed any notice at all was taken of it, as utterly valueless. In fact, we believe that not a single person could have been found, however well versed in telegraphy or electricity, who would have given a hundred dollars for the patent within three months after its issue.

. . . We very much doubt if it could now be purchased for \$25,000,000. It is probably by far the most valuable single patent which has ever been issued.

During the winter of 1876 and the spring of 1877, there appeared in the daily papers a number of references to Graham Bell's statements concerning the general use of the telephone, the central telephone exchange system, aerial and underground cables, the long-distance service, etc. Lack of space prevents the citation of all, but the general tenor of his remarks are shown in the following excerpts.

The Boston *Sunday Herald*, of October 22, 1876, declared that the future possibilities of the telephone can scarcely be overestimated. The economic and other advantages thus opened to the contemplation of the thoughtful are too self-evident to be descanted upon.

On February 13, 1877, the Boston *Globe* in reporting Graham Bell's lecture before the Essex Institute, at Salem, said:

We have the pleasure of presenting to our readers this morning, the first despatch ever sent to a newspaper by the newly invented telephone. . . . Professor Bell closed his lecture by briefly stating the practical uses to which he was confident the telephone could be applied.

On Wednesday evening, April 25, 1877, Graham Bell delivered a lecture in Huntington Hall, Lowell, and the next day's *Lowell Citizen* contained a report of the lecture reading in part as follows:

At about half-past nine o'clock Prof. Bell spoke of the possibilities of the future regarding the telephone. He predicted that private houses would be connected with stores and offices and shops, and orders for the day's dinner as well as important business of every kind could be transmitted without leaving the room. In the future merchants would be enabled to order goods from New York, Boston or other cities by word of mouth, instead of telegraphing or taking a long journey.

That the editor of the *Citizen* was impressed with Alexander Graham Bell's enthusiastic presentation of his subject, and realized that this uplifting faith in the future of his invention must be based on an accurate knowledge of what it might accomplish once its function was fully comprehended, is evident in the leading editorial. And this editorial is remarkable in that it is the first of all editorial references to 'a central telephone office,' and the first of all favorable comments on the probable success of exchange telephone service. In part the editorial reads:

Professor Bell believes that in the near future a central telephone office will be established in all our cities, with which the police, the fire department, most business houses and many private residences will have connections. When this is done any person having the connection can call the police, report a fire, order a dinner or chat with a neighbor without leaving the room.

Graham Bell also lectured in New Haven on April 27, in Manchester on May 8, in Springfield on May 12, and then he went to New York and delivered three lectures in Chickering Hall. The third lecture was delivered on Saturday evening, May 19, 1877. Therein he referred to the convenience that long-distance service between Boston and New York would be to the business man, touched upon the use of

the telephone booth not then devised, and upon the value of the central exchange as a public convenience, stating as one illustration:

It is a rainy morning, and Mrs. Smith does not want to get wet. She calls on the central office to connect her with Mr. Jones, the butcher. It is done. So with offices and houses, or workshops, and many other places.

Reports of other lectures could be cited, but a sufficient number have been shown to illustrate how clear was Graham Bell's conception of the usefulness and economical advantages of telephone exchange systems and long-distance telephone service before either one existed. And by reason of his cheery optimism and his logical, convincing arguments that the establishment of telephone exchanges in every city would necessarily follow, and that telephone service would become an indispensable feature in business and social life, his associates gained greater courage to push the exploitation of the telephone.

After considering the several plans presented for the future conduct and expansion of the new business, it was decided to adopt the plan of interesting local capital and cooperation in the establishing of local exchanges and to issue to these local organizations short-term licenses covering a period of only five or ten years. With this end in view agents were appointed to solicit customers in given territory on a commission basis ranging from 25 to 50 per cent.

Where the intention was to construct and operate a local plant the exclusive right to operate under all Bell patents was granted with the proviso that the parent company, if it so desired, could purchase the property of the local company at cost, or at an appraised valuation at the expiration of the license. Then it was arranged that the telephones should never be sold during the life of the patent, but leased, the technical title of ownership being reserved to avoid legal complications, and also to secure territorial rights in the event of default of payment of the agreed royalties by the local companies. Thus the parent Bell company never granted to any operating company any right or interest in its patents nor the right to manufacture or sell telephones.

Within a year this method of locally introducing the telephone met with a cordial reception on the part of many with a speculative bent of mind, if not by permanent investors, and thereafter it became a comparatively easy task to interest local capital in local exchanges having a license covering a period of only five or possibly ten years. The royalty required of the local licensee, amounting to \$7 a year for each instrument, was not in the beginning considered exorbitant by local owners familiar with the heavy yet legitimate payments necessary in protecting the licensees from infringing competition, for necessary subsidiary patents, as well as for experiments, the patent risk, and the endless litigation. And when the hard times of 1884 came, and again in 1885, the parent company made many concessions and introduced a sliding scale of rentals that materially lessened these royalty payments.

Even from the first it was perceived that a long-term license would not be equitable to both parties, owing to the new conditions that were arising and would necessarily continue to arise from month to month. With growth and development would come a broadening experience of great value to both operating and parent company, and a lessening of timidity on the part of capital. It was this fear on the part of investors that rendered necessary the issuance of separate licenses for neighboring cities or adjoining territory, or for towns widely separated. Yet it was obvious that the near future was certain to bring changed conditions that would strongly emphasize the necessity for merging several exchanges or even all lines and exchanges within a state under one management and governed by one policy.

Thus it came about that during the four years, 1878-81, local telephone exchanges were established in many towns by individuals or small companies, on the understanding that the local owners were to furnish all the capital required to properly start and develop the industry, while, in return, the parent company would supply the telephones as fast as required, and would protect and defend the exclusive rights to operate under the Bell patents.

Early in 1877, Mr. Frederic A. Gower was appointed 'general agent for the Bell telephone' for all of New England. He assisted Graham Bell in a number of lectures, delivered a number of lectures, and visited nearly all the larger cities in his territory in the effort to secure local capital and cooperation in establishing telephone exchanges. Then he tendered his resignation to take effect on January 1, 1878, in order that he might spend much time in introducing the telephone in European cities. Thus, to take up and systematically continue the work that Mr. Gower had been so actively engaged in, a second organization was formed that may properly be referred to as a subparent company, as it enjoyed equal rights with the first company within a limited territory.

This second company was incorporated on February 12, 1878, under the general laws of the Commonwealth of Massachusetts, with an authorized capitalization of \$200,000, all of which was issued in return for \$50,000 in cash and for certain patent rights and other privileges valued at \$150,000. Exclusive rights 'to use, license others to use, and to manufacture telephones in the New England States,' were granted to it, and during its brief existence it endeavored to thoroughly develop its allotted territory. It secured the right to erect poles and wires in a number of cities and aided in the organization of a number of local telephone companies. Though named the New England Telephone Company it was never in any way related to the later and now well-known New England Telephone & Telegraph Company of Boston.

The stockholders in the New England Telephone Company were practically the same persons who composed the membership of the original parent company, the Bell Telephone Association. The officials were: President, Gardiner Greene Hubbard; treasurer, Thomas Sanders; general agent, George L. Bradley; clerk, Thomas B. Bailey. Incidentally it is worthy of note that since its organization Mr. Bailey has been the purchasing agent of the American Bell Telephone Company. On July 27, 1878, Mr. Hubbard resigned the presidency and Mr. Sanders was elected in Mr. Hubbard's place, while Mr. Bradley succeeded Mr. Sanders as treasurer. Until February 15, 1879, the New England Company occupied room 43 in the Sears building in Boston, when it moved to room 52 Mutual Life Insurance building.

Meanwhile Mr. Hubbard found it difficult to borrow the funds necessary to carry on operations outside of New England. Friendly bankers had loaned generous amounts, but when further advancements became imperatively necessary, they asked for a more tangible form of collateral than certificates issued by an unincorporated association, and it was suggested that the stock certificates of a conservatively incorporated and wisely managed company might be acceptable as security, if offered at a low valuation. So, on July 30, 1878, the second of the parent companies was incorporated under the laws of Massachusetts to transact a general telephone business in all of the United States outside of the New England States. It was capitalized at \$450,000, and that amount of stock was issued in return for a cash payment of \$50,000 and all the rights and privileges held by its predecessor, the Bell Telephone Association. Its officials were: Trustee, Gardiner Greene Hubbard; treasurer, Thomas Sanders; electrician, Graham Bell, and superintendent, Thomas A. Watson. At first its headquarters were at the Williams factory, 109 Court Street, Boston, but in August, shortly after its organization, it moved to New York City and occupied rooms at 66 and 68 Reade Street. It bore the name: Bell Telephone Company.

The interest awakened in the development of the telephone industry through the activity of these three organizations and their agents created a volume of business, the character of which necessitated the formation of a broader organization, and resulted in the birth of the third parent company, the National Bell Telephone Company, as detailed in Chapter V. The company was organized on March 10, and its charter issued on March 13, 1879. It was formed through the amalgamation of the New England and the Bell Telephone Companies, and succeeded to all the property and patent rights and privileges of both these companies. The new company was capitalized at \$850,000, and this amount of stock was issued in return for telephone exchange and manufacturing property representing a cash investment

of \$306,900, for \$6,500 cash in treasury, and for all the stock of the Bell Telephone Company, \$450,000, and of the New England Company, \$200,000, valued at \$536,600. Within five months after its organization, the headquarters of the National Company was moved from Reade Street, New York, to 95 Milk Street, Boston.

Under the wise and liberal guidance of President William H. Forbes, the practical progressive policy of the National developed a volume of business so large and of so varied a character as to make clear the need of a still broader parent organization able ultimately to assist in carrying the financial burdens of any or all of its operating companies, and to extend substantial encouragement for extended development. Then the successful outcome of the bitter contest with its competitive opponent, the Western Union Telegraph interests with a total of seven thousand established telegraph offices, had drawn to the National company the thoughtful interest of capital seeking productive fields for investment, and soon investors began to overrun the telephone field.

Thus, after a very strenuous life of fifteen months, the National was absorbed by the fourth of the parent companies, the American Bell Telephone Company. This fourth organization was granted a special charter by the commonwealth of Massachusetts, on March 19, 1880, which was slightly amended as of May 21, 1883, in so far as it relates to the holding of stock in the operating companies. The American company desired to have an authorized capitalization of \$15,000,000, but the legislature limited the amount to \$10,000,000.

At a special meeting of the stockholders of the National Bell Telephone Company, held on Monday evening, March 29, 1880, it was voted unanimously to sell all the property of the company to the American and to transfer the same as of May 1, in return for payment in the form of six shares of the capital stock of the American Bell for each share of the National. This was a reasonable price to pay, as shares of the National had sold as high as \$960, according to a statement in the Boston *Herald*, though the par value was only \$100, while the last sale of 500 shares had brought \$600 a share in December, 1879.

Two days later the National stockholders received a printed notification reading in part:

The American Bell Telephone Company has been organized with a capital of \$7,350,000, divided into 73,500 shares of \$100 each. This new company has voted to purchase all the property and assets of the National Bell Telephone Company for the sum of \$6,500,000, payable in stock at par (65,000 shares) and to offer the remaining 8,500 (\$850,000) at par to the stockholders of the National Bell Telephone Company as of date of April 1, 1880.

Of the 65,000 shares transferred to the National Company in return for all its property, patents, etc., 51,000 shares, or \$5,100,000 were distributed among the national stockholders according to their respective

holdings; 1,145 shares were used to take up the convertible notes issued; 1,500 shares were sold by the trustees in open market for \$332,935.75, and 1,050 shares were held by the trustees to use in liquidating future claims.

The new company occupied offices at 95 Milk Street, Boston, and at the first meeting the following officers and directors were elected:

W. H. Forbes, President.	T. A. Watson, General Inspector.
T. N. Vail, General Manager.	A. Graham Bell, { Consulting
W. R. Driver, Treasurer.	Francis Blake, { Electricians.
O. E. Madden, Superintendent of Agencies.	J. P. Davis, Engineer.

DIRECTORS

William H. Forbes.	Francis Blake, Jr.	Alexander Cochrane.
Charles S. Bradley.	Richard S. Fay.	George L. Bradley.
Gardiner Greene Hubbard.	William G. Saltonstall.	C. P. Bowditch.
Thomas Sanders.	Charles Eustis Hubbard.	

The successful launching of the American Bell Telephone Company, notwithstanding that the three earlier companies had never paid a dividend, was a splendid tribute to the intelligent persistence displayed by the pioneer advocates in promoting so serviceable a public utility, as well as to their executive and financial ability. And the magnitude of the task of merging all these interests into one comprehensive organization may be more clearly realized in the brief statement that in its consummation there were involved about five million dollars in cash, and a million in property and patents. In 1880, six millions was a sum relatively many times greater to financiers, when million-dollar corporations were more scarce, than at the present time, when a hundred millions may be a fair and a necessary capitalization.

In his annual report for the first fiscal year, ending February 28, 1881, President Forbes of the parent company said:

After two years passed in a struggle for existence, and a third largely devoted to the settlement of disputes inherited from that contest, the owners of the telephone patents, at the beginning of their fourth year, for the first time find themselves free from all serious complications, with nothing to prevent the company from directing its whole working force to the development of the business, and with a well-defined policy for its future operations, which seems to be working well in all parts of the country. . . .

A large amount of work has been done in the electrical and experimental department, both in examining new inventions and testing telephones and apparatus, and in studying the question of overhead and underground cables, and the improvement of telephones and lines, for both short and long-distance service. This work is expensive, but it is of the first importance to our company, and must be continued.

Much of the electrical and legal work of these first years of the company, and, indeed, some of our expenses incurred in studying and classifying the business, are substantially for the establishment of the property, and might be charged to construction and capitalized, but the directors have preferred the more conservative policy of charging everything to operating which could reasonably be put there, although the result upon the books appears less favorable, in consequence, than the business prospects might warrant us in exhibiting.

THE BALSAM PEAKS—THE HEART OF THE SOUTHERN
APPALACHIANSBY SPENCER TROTTER
SWARTHMORE COLLEGE

AN APPRECIATION

FROM a field near the upper end of the town you could see three mountain peaks, two near together and one farther to the west, that stood out sharply against the cool, yellow evening sky, less defined when bathed in the shimmering bluish haze of diffuse sunlight or when brushed by the trailing vapors of passing clouds, but at all times fascinating in their lofty isolation and in the invitation which they held to adventure and to explore. These were the Plott Balsams. Away to the southeast, beyond Deep Gap on the farther side of Lickstone, we knew of a trail that followed the crest-line of the Divide, higher and higher until it reached the summit of the Richland Balsam, second only to Mount Mitchell in the galaxy of the Southern Appalachian peaks. Down the main street of the town one's eye went beyond the narrowing vista of houses, miles away to the blue uplift of Crabtree Bald. To whatever point of the compass you might look there were mountains, but the Balsams held the loadstone that drew us to their summits. Some persons there were who declared that they could detect a trace of balsamic fragrance when the wind was westerly, wafted from the high peaks six miles away. I, for one, could never reach this exalted state of sense or of imagination, whichever it might be. No man, however, is a competent judge of the condition of another's sensorium. It is enough if he follow his own nose and its teachings.

One Sunday in mid-June we essayed the Enos Plott Balsam by the trail that a horse could follow to the summit. As we turned the corner of a street, where the town fell away into the valley of the Richland, a Carolina wren was proclaiming the joy of life in no uncertain voice. This I remember, and also that the air was crystal clear and flooded with sunlight. Our way led for some miles along a road that followed the stream through the farming land of the valley, past an occasional house and barn and the patch of tobacco that was grown for home consumption. A 'neighborhood' road branched off from the main-traveled highway, and this we followed until it ended in the woods at a fence on the other side of which the trail began. Here we plucked some sprigs of the wild indigo (*Baptisia*), a plant with yellow, pea-like

blossoms, and each of us decorated his horse's head as a sure remedy against the tormenting flies.

I never think of this fence and its old gate through which we passed, with the narrow trail starting abruptly up the steep slope of the wooded mountain side, without vaguely picturing the wicket-gate through which Christian went at the outset of his journey. If ever there was a land of promise surely it must be at the farther end of that toilsome trail with glimpses of the Delectable Mountains here and there on the more open stretches of its upper levels.

For long the beasts scrambled upwards, stopping to breathe where the steepness was broken by some irregularity. We held on bravely to the manes, leaning well forward, and pressed our legs close as we scraped by the trees that beset the trail. It was a long ridge that the trail followed, the land on either side falling away quite sharply. Higher up the woods became more open, with little undergrowth and long vistas among the trees. The bloom-covered bushes of the flaming azalea (*Azalea lutea*) were scattered far and near, glowing spots of color in the sunlit spaces of the woods, and the crisp leaves of the galax (*Galax aphylla*), shining bronze and green, spread in thick patches along the way. The woods on this midway portion of the mountain were for the greater part made up of oak and chestnut. Lower down, near the foot of the mountain and in the deep, moist coves between the ridges, the tree life was more varied and the primeval forest more luxuriant and jungle-like in character. There the buckeye (*Æsculus*) and the tulip tree (*Liriodendron*)—the yellow poplar of the lumbermen—grew to truly magnificent proportions, and many other Carolinian forms prevailed.

In the dry, open woods on Huckleberry Knob, a wild turkey suddenly started up before us and ran swiftly down the slope. It was a bit of the primitive wilderness life and gave a fine touch to our adventure. Huckleberry Knob is one of the three Balsam peaks that we had so often gazed at from the town; the lower one of the two that appeared close together. It was, in reality, but a hump on the southern shoulder of the main Balsam, the summit of which we now for the first time in our ascent caught a glimpse of through an opening in the woods, towering far away to the right—a stark peak with a bristling mane of fir forest. We were still among the oaks and chestnuts on Huckleberry Knob, some distance below the fir zone, but even at this altitude the air had a cool, autumnal snap and I was glad to have a thick jacket which had been uncomfortably warm in the valley. The hardest part of the climb was over, so White told us, and the horses had a comparatively easy time following the trail, which now led for some distance along the upper edge of a steep slope. The soil was a rich black mold of considerable depth that made a precarious footing, especially on the

steeper parts where a horse would now and then slip badly. Scattered droves of half-wild hogs were rooting in the earth in the woods below us; lean, dark-colored fellows with long legs that bespoke a life of activity.

The oaks and chestnuts became straggling and scrubby; there was more sunlight through the woods, with an occasional glimpse of a distant mountain; sky-lines across gulfs of hazy blue. It was here that we saw the first evergreens—a few scattered trees along the upper edge of the deciduous zone. The tannin-smelling woods of oak and chestnut presently ceased altogether and we passed into a boreal forest, the trail winding through dense clumps of spire-topped firs and spruces, interspersed with open, grassy parks. One could not help breathing deeply in this rarer air, redolent with the aromatic fragrance of balsam that recalled long-forgotten Christmastides. I should not have been surprised if the paint and varnish smell of new toys had greeted me on these Balsam heights. Dainty bluets (*Houstonia*) of the northern spring made bright patches on the green moss, and here and there the *Clin-tonia borealis* reared its wand of yellowish-green flowers above the broad, glaucous leaves. We had left summer on the lower slopes; it was spring on these mountain tops; we had left Carolina in the valley, with its passion flowers and its wild indigo; it was Canada that we found above the six-thousand-foot line.

There was an impressive stillness about these evergreen solitudes that heightened the feeling of remoteness and isolation. Nor was bird life at all conspicuous, only the occasional chip of a Carolina junco. The tinkle of a bell sounded pleasingly when some mules met us on the trail, one with a bell fastened about its neck. White and Chalfant began talking of the fine pastures on these high slopes, where stock, from farms in the valley, is turned out to range at will. The animals are often more than half-wild in their freedom, and this is especially the case with the young cattle and hogs that are born there and that frequently reach maturity before seeing a man.

The trail presently led us into one of these alpine pastures—a broad, open meadow on the rounded shoulder of the mountain, falling away on either side into the fringe of evergreens. Here the juneberry (*Amelánchier*) was growing, with its red fruit clusters, and the mountain holly (*Ilex monticola*), and here and there a gray bowlder outcropped above the rich grass turf, and here and there a scattering clump of spruce and fir. Some distance off a number of young cattle were grazing, and farther down the slope some sheep and horses watched us with mingled distrust and curiosity. It was like riding along the roof of the world to traverse this sky-land meadow, lifted up like some enchanted country.

From this meadow our way led up the western flank of the peak

through the groves of mountain rose bay—the Catawba rhododendron (*R. Catawbiense*)—that grows only on the highest summits of this mountain land. On the summit of Lickstone Bald we later found it a shrub scarcely three feet in height, but on the Plott Balsams it was arborescent—a tree twenty feet high—and we rode the rest of the way under bowers of lilac and rose bloom. What I had read and heard of the scenery of Himalayan slopes was visibly present—the gorgeous blossoms of rhododendron jungles and the dark forests of fir bathed in the azure light of the upper world. Nowhere on this continent can one find a nearer approach to Himalayan vegetation, and I would fain add scenery—save for the absence of that snowy range that towers above the tree-line zone. The fir tree of these Carolina mountain tops is Fraser's balsam fir (*Abies Fraseri*), a distinct species, though closely allied to the common fir of northern evergreen forests. The same resin blisters are found on the trunk and limbs as in the northern species, and it is the exudation from these that fills the air with balsamic fragrance. The woodsmen of this region call the fir a "she balsam" in contradistinction to the spruces, which are called "he balsams" and on which no resin-filled blisters are found.

Plott Balsam is a more decided peak than any of the surrounding mountain summits. It falls away steeply on all sides from a level space on the top scarcely larger than the flat roof of some tall building. This gives one the impression of great upliftedness—of standing on the pinnacle of an exceeding high mountain and beholding the kingdoms of the world. The timber had been felled on the very summit, presumably to give a lookout, and we had a superb view of the valley of the Richland more than three thousand feet below. In every direction mountain masses lay before us—range beyond range—like a vast relief map. To the north, on the farthest verge of the horizon, loomed indistinctly the range of the Great Smoky. Toward the east and south the eye swept from Pisgah along a quadrant bounded by the hazy uplift of the Blue Ridge more than thirty miles away. It was not this vista of mountains, however, that impressed me most. It was the vastness of the sky with its cloud pageant. Here was the birthplace of the cumuli. Wisps of vapor, formed in the uprising currents on some high mountain top, streamed off in the wind like a banner, grew and grew, rolled into a fleecy mass, waxing greater, until the stately pile of the cumulus floated on with its fellows—a Phæacian fleet that would vanish in the sunset on some distant horizon.

The cumuli breed the thunderstorms that gather over these mountains in the early afternoons of summer. During the latter part of June and through July "thunder heads" would be hovering over the western ridges, casting their deep shadows on the slopes and the valley. Downpours of rain were frequent and one soon got accustomed

to a drenching. There is a certain feeling in being overtaken by these mountain rain-storms that lifts one above the mere petty annoyance of wetness. It savors of primitive things and is probably a reversion to remote ancestral ways of life. On one occasion Lucasta and I, with two piebald mares and a "hound dog," made the ascent of the Plott Balsam. It was a lowering morning and did not promise much in the way of views, but a wedding anniversary was to be kept in cloud-land—as near as possible to the place where such blissful states are said to have their origin. Beyond Huckleberry Knob we found ourselves in a driving mist and heard the rumble of thunder in the ravines on either side. We missed the trail above the alpine pasture and, tying the horses in the firs, blazed our way up the peak. The air was clear of mist on the summit; the cloud was beneath us and we looked out on its gray vapors as one might look upon the sea from an island shore. A rift suddenly disclosed a bit of the valley—a fleeting glimpse, for the dull mass as quickly rolled together again. We congratulated ourselves on the day. You may behold the expanse of land and sky many times from these outlooks, but rarely does it chance that one sees the earth through a cloud rift. The peak of Plott Balsam was above the cloud; when we returned to the horses it was to find them still in the same bewildering mist. We shared some biscuits with the companionable hound, the horses munching their measure of grain, and all the while the cloud drenched us and the dripping firs distilled a fragrance that entered into the soul. There was a fine sense of being a part of the primitive life of things—of the mountain, and the weather, and the vegetation—enough of the aboriginal man and woman in us to find joy in such surroundings.

The rain that had swept the slopes below the alpine meadow had made the trail so slippery that walking was preferable to riding, especially where the horses had to slide down the steeper parts. There had been a heavy thunder-storm in the valley and all the while we were in the cloud itself and above it, seeing no lightning at all from our elevation.

Lickstone Bald is a very different summit from the Plott Balsam. It begins as a long upward-trending ridge from Deep Gap, through dry open woods until it reaches a deciduous timber-line above which it is treeless—no evergreens and no arborescent rhododendrons. One gets the impression of riding along the ridge pole of an immensely high-roof, so narrow is the crest-line and so steep the side slopes. The trail ends abruptly on the brow of a sharp declivity that falls away to the lower slopes for several thousand feet. These lower slopes about Lickstone are covered with a magnificent forest of oak, chestnut, magnolia (*Magnolia Fraseri* and *M. acuminata*), tulip or yellow poplar, buckeye, sourwood, and many other varieties. The showy flower-clusters of the

sourwood (*Oxydendrum*) are visited by great numbers of wild bees and sourwood honey has a reputation that is not confined to the locality. I have some pleasing memories of mountain breakfasts sweetened with this dainty product of the wildwood. Eating wild honey, like drinking goldenrod tea, or devouring handfuls of wild berries, or partaking of any natural harvest, gives a fine edge to the business of eating, at least to the imaginative side of it.

On the trail between Deep Gap and the Allen Branch, and not far from the mica mines on the western side of Lickstone, stood the cabin of Arnold Guyot's old guide, Wid Medford. Guyot spent much time in these parts, surveying and studying the various mountain groups. A peak of the Great Smoky Mountain bears his name, and the United States Geological Survey has memorialized the work of this pioneer in geographical science by naming one of its topographical sheets "Mount Guyot." We took refuge one afternoon under Medford's porch during a thunder shower and the old man talked about Guyot, chuckling with great glee over the wrath and discomfiture of the near-sighted professor when on a certain occasion he had blundered into a yellow-jacket's nest. From the old fellow's yarn I gathered that he had purposely led the unsuspecting geographer into the trap, by way of a joke; and the memory of it was still very green. If only I had heard this story of Medford's when as a boy I struggled with a Guyot's School Geography, how I should have envied the guide and the yellow-jackets.

Southward from Deep Gap a trail leads up to the crest of the Divide—the water-parting of streams that flow west into the Tuckasegee Branch of the Little Tennessee, and east into the west fork of Pigeon River. The trail follows along the summit for many miles, through a dense forest of balsam fir and close to the precipitous eastern side, from which one has an overlook of the Pigeon Valley three thousand feet below. A spongy carpet of bog moss (*sphagnum*) gives a truly Canadian touch to the fir forest of the Divide. To look down from these boreal heights on a valley where sorghum is growing, where cardinals are whistling, and passion flowers are blooming, lends another point of view to one's ideas of geography. The trail goes steeply up from Deep Gap to the top of Cold Spring Mountain, where Magee and I ate our lunch, smoked a pipe of tobacco, and drank crystal water from the spring. Beyond Double Spring Gap the crest-line of the Divide gradually rises to the summit of the Richland Balsam, six thousand, five hundred and forty feet above the sea-level. There is a glorious view of peaks and ridges from this Balsam top, with the great dome of Mount Mitchell (6,711 feet) rising above the Black Mountain group, but I did not get the same sense of upliftedness as I did on either of its lesser neighbors—the Plott Balsam and Lickstone Bald.

This I think is because so many high ridges are in the immediate vicinity and there is no near view of a valley.

Between Double Spring Gap and the Richland we fell in with a "moonshine" scout, armed with a long-barreled gun, who told us he had been watching for a bear. Our presence had evidently been heralded by some one sent ahead from a cabin on the side of Lickstone where we had stopped early in the forenoon to inquire the way. The man was quite affable when he found out who Magee was and that we were on a harmless tramp, looking for plants and mountains. He went with us to the summit of the Richland, pointed out many interesting landmarks, and offered to take us to his home to spend the night. I gave him a "poke" of fine-cut tobacco, which he said was too soft for him, but that his little boy would be glad to have it. Thus I unwittingly encouraged a vicious habit in one of tender years. Every one uses tobacco in these mountains, the women taking it in the form known as "dipping"—a stick, one end of which is moistened and dipped in snuff, held between the gums and cheek. On our way back we met another man carrying a heavy sack on his shoulder; undoubtedly corn destined for some secluded spot where the alchemy of a crude still would transmute it into golden "moonshine."

An almost obliterated trail leads from the Richland Balsam, by a fir-crowned ridge to Caney Fork Bald, the treeless top of which is a grazing range. We saw it first against the glow of a western sky, the pasture slopes of its dome-like crown bathed in cool shadows. Scattered groups of cattle, sheep and horses gave a truly pastoral touch to the scene. There is something fascinating in these remote mountain pastures with their vast reach of sky, and girt about as they are by a world of forest-clad ridges. They are the park-lands of the Southern Appalachians.

The Balsam peaks, with their glorious alpine meadows, their boreal forests and rhododendrons, and the sylvan wealth of their lower slopes, lie in the very heart of the region which the government of the United States now has under consideration to purchase and set aside as a national forest reserve. Apart from the wisdom of thus preserving a vast tract of forest land and conserving the water-supply of many important rivers, there is, in this idea of an Appalachian National Park, an appeal to the aesthetic side as well—to that love of wild, undisturbed nature and of mountain scenery that seems to be a natural instinct in large numbers of our people. John Muir has sounded this note in his delightful book on the national parks of our western country. The Southern Appalachians have likewise a charm of their own. To wander over these mountain meadows and balsam-covered peaks is to enrich one's life and store the mind with fragrant memories.

THE RE-AWAKENING OF THE PHYSICAL CONSCIENCE

BY RICHARD COLE NEWTON, M.D.

IN the recollection of men not yet old, such a thing as physical education was scarcely thought of in America. About fifty years ago Dr. Oliver Wendell Holmes wrote: "I am satisfied that such a set of black-coated, stiff-jointed, soft-muscled, paste-complexioned youth as we can boast in our Atlantic cities, never before sprang from loins of Anglo-Saxon lineage. . . . Anything is better than this white-blooded degeneration to which we all tend."

This condition of things had not, however, been reached without some concerted efforts to prevent it. In 1826 Harvard had started the first American college gymnasium in one of its dining-halls, and later in the same season, a number of gymnastic machines were put up on the playground known as the Delta. Gymnastic grounds were established at Yale the same year, and at Williams, Amherst and Brown in the year following. Competent instructors, however, were not to be had and no one knew how to produce them, so the movement was abandoned in five years time.

About thirty years afterward under the management of Professor Hitchcock, compulsory gymnastics were instituted at Amherst with very happy results. Within twenty years about fifty other institutions of learning had followed Amherst's lead; and now at Yale, Columbia, Princeton, Oberlin, the University of Pennsylvania and the University of Wisconsin gymnastic exercises are compulsory for all students for at least a part of the college course. The excellent results of the prescribed drills and exercises at Annapolis and West Point have, no doubt, contributed to the growing conviction that proper bodily development should be a part of every educational system. The students in many schools, as we shall see later, have taken their own physical education in hand. The present passion for athletic sports seems well-nigh universal and has gained such headway that it is evident that it must be taken very seriously. Over \$1,000,000 are annually spent on college athletics in the United States, an increase of five-fold in the past ten or twelve years, and some young men, at least, unquestionably go to college for the specific purpose of playing upon the university teams. The stroke oar of the university crew, is by many, perhaps a majority, of his classmates held in higher honor than the valedictorian. Even as some of the youth of Hellas preferred the laurel crown, won in

the Olympian games, to the prizes offered for the greatest achievements in poetry or art.

Eighty years ago there was not a college gymnasium in the United States, to-day a college without a gymnasium is unknown. Eighty years ago gymnastic instructors were not to be had and no one in America knew how to produce them. Now there are a number of normal and training schools turning out physical instructors and yet the demand keeps so far ahead of the supply that such teachers are paid, when engaged, about twice as much as the teachers in other branches, and, as for the colleges, gentlemen of liberal culture, graduates in the arts and in medicine, are glad to accept positions as directors of the gymnasia and of the physical training.

In two hundred cities of the United States there were three years ago vacation schools, and schools of like character were projected in Buenos Ayres and Amsterdam. Similar schools are also in operation in London. These schools are chiefly for the teaching of manual training, games and deportment, and employed in New York City 1,400 teachers in 1903. In St. Louis a practise was instituted of taking the older boys in the vacation schools to see the principal base-ball games played in the city, as a means of enhancing their interest in manly sport.

As the result of a *questionnaire*, Dr. McCurdy, of the Springfield Training School, found that out of 555 cities in the United States, from which he got replies, 128, or 23 per cent., employ special physical training teachers (102 men and 189 women). Practically all the schools in the 555 cities had playgrounds. Of 427 schools not employing special physical training teachers, 190 used some special system of physical training. Of the high schools of the 128 cities employing physical training teachers, 113, or 88 per cent., have football teams, and in 386 other cities, 319, or 83 per cent., have football teams, while half as many of the grammar schools in both classes had football teams. In 36 per cent. of the cities where special physical training teachers are not employed, and in 68 per cent. of those where such teachers are employed, there are in addition special athletic instructors, or "coaches," for the most part under the direction of the students themselves. It is a commentary on the courage of American boys that there were more football teams than baseball, basket-ball or track teams in these 514 cities. The large majority of the school superintendents approves of competitive athletics in the high schools. Dr. McCurdy speaking of the need of gymnastic exercises for the girls says, "adequate and satisfactory teaching will be absolutely necessary for both sexes in the near future."

Dr. Luther Halsey Gulick, director of physical training in the New

York City public schools, has just submitted a statement in regard to the athletic clubs formed among the male scholars in the schools. These clubs are maintained by the boys themselves with the aid of the teachers and some outside friends. President Roosevelt is honorary vice-president of their athletic league and other distinguished men are serving as its officers. Especial stress is laid in the statement upon the devotion of the teachers, of whom 411 did volunteer service during the past year in helping the boys with their athletics after school hours. Had they been paid for this work at the same rate which they are paid for their regular duties, they would have received in the aggregate \$120,000, a very handsome contribution to the cause of school athletics; especially when it is remembered that many teachers require the hours after school for post-graduate and other work necessary for their own professional advancement.

Two hundred and twenty-four schools in Greater New York reported on athletics last year, of which 83 had regular organizations and 165 had available grounds for practise. The students pay dues into the athletic treasury at an average rate of twenty-eight cents per term, and 21,873 of them took part in the athletic sports during the year. Dr. Gulick has under him a supervisor of physical instruction in each borough and a total of fifty or sixty teachers in this branch of public instruction. The work has been admirably organized. Similar organizations have been started and have made excellent progress in Philadelphia, Boston, Chicago, and other cities. Emissaries from various foreign governments have visited the physical training schools of New York to study their methods. Two or three delegations have been here from Japan.¹ The director of physical training in the schools of the City of Mexico has recently visited New York on his tour around the world to inspect the various systems of physical instruction now in use, and upon his recommendation three men and three women will be sent to New York to receive the technical training requisite to fit them to teach physical education in the City of Mexico. One such teacher (a woman) has already gone from New York to work in the City of Mexico.

The United States government is now sending the director of physical training at West Point to visit England, Germany, France, Italy, Austria and Sweden for the purpose of thoroughly studying the systems

¹The great interest which Japan has always taken in matters of physical education showed itself in 1876 by the visit which her vice-minister of education paid to Amherst College under orders from his government to study and report upon the system of physical instruction in use there. This was followed by a request from the Japanese government that an instructor be sent from Amherst to introduce Dr. Hitchcock's system into the government schools in Japan. The request was complied with to the great satisfaction of the Japanese.

of physical training practised in the armies of those countries. The Greek government has recently requested the authorities of Harvard University to send information regarding American gymnasia that will aid in constructing and equipping the gymnasium at Athens.

The Sunday Schools have also begun organizing athletic leagues. In 1904, twenty-five Sunday Schools in the borough of Brooklyn organized an athletic league which had a membership of fifty schools in a few months. Notices now appear in the daily papers of athletic meetings, including wrestling and similar sports, by church societies. While this might be regarded in the light of an effort to fight the devil with his own weapons by providing some sports that will really attract men and boys to the church society meetings, nevertheless it is due in part at least, to the widespread demand for physical education; a phase of modern life long since utilized by the Young Men's Christian Associations. Of late years, however, the increased demand for this kind of teaching has taxed the resources of the associations heavily, and the work is constantly growing, as the following figures will show: The attendance at the Young Men's Christian Association gymnasia in this country has increased from about 50,000 ten years ago to 154,000 in 1906, or over three-fold. All the extension work, so called, which is the teaching of physical exercises in schools, colleges, churches, clubs, etc., by Christian Association men, has been developed in the past decade, whereas, "the shop work," namely, teaching the industrial classes right habits of living, has been taken up within the past three years, and 271 leaders are engaged in work of this kind.

Ten years ago, eight per cent. of the Young Men's Christian Association directors had received technical preparation as physical instructors. To-day, thirty-nine per cent. have received such preparation. So in the Young Women's Christian Association physical instruction has become an important feature. There are at present over 80 associations, out of 138 reporting, giving such instruction, whereas sixteen years ago there were only two. Of a total membership of 68,803 women, there were in 1905 11,153, or 16 per cent., enrolled in the physical training classes, as against 9,001, or 13 per cent., enrolled in the Bible study classes.

That other countries feel the working of the same leaven, the following incident testifies: Not very long ago, the Pope consented to act as patron of the athletic societies of Italy, and invited them to give exhibitions in the courts of the Vatican. This innovation met with great opposition from the members of the papal court. His Holiness, however, was not to be dissuaded from his purpose, saying to the protesting cardinals, "Come and see these brave boys, you will be rejuvenated by fifty years, and they will gain from it in the health of their bodies, and above all in that of their souls." Accordingly, races, trials of strength and gymnastic contests were held in the great courts and

gardens of the papal palace, the contestants receiving over two hundred gold and silver medals from the Pope, who had caused temporary thrones to be erected for himself and his court from which they witnessed the sports. Even in the island of Porto Rico athletic contests are superseding cock-fighting as a national amusement.

Not only, however, is there an unwonted activity in physical education, but the subject of personal and general hygiene never before received one half the attention that it does at this moment. The city of Philadelphia alone spends more resources and employs more agents in the interests of public health to-day than did the whole English-speaking world a century ago. Not only has the movement to give every child, rich and poor alike, a good physical education become quite general, but steps are also taken to guard his health from contagion and from every injurious influence during his school life.

The first international congress on school hygiene was held in Nuremberg in 1904 and has been followed "by increased literary activity in nearly every country." The second is called to meet in London in August, 1907. King Edward will be the patron of the congress, and Sir Lauder Brunton its president. Steps are being taken to interest the entire civilized world in the effort "to promote by continued activity, in any way the cause of health and knowledge in education." Medical inspection of schools was introduced in Boston in 1890; in Philadelphia in 1892; in Chicago in 1896; and in New York in 1897. In Brussels special school physicians were first appointed in 1874. Now dentists and oculists have been appointed to the schools, and instruction in hygiene is given in eighty-five per cent. of them. Similar measures have been inaugurated in nearly every capital of Europe, and in the high school of Brookline, Massachusetts. The Russian Society for the Preservation of the Public Health has recently arranged a program for the investigation of the hygienic condition of the schools, and probably in every city of any size in America and many country places as well, medical inspection of schools is now a regular practise.

The great educational value of play, as such, has at last begun to be recognized. A German commission some few years ago visited the English public schools under instructions to study the influence of the games and sports carried on there upon the physical and intellectual development of the students. Their report was such that steps were immediately taken to introduce athletic sports and games into the German schools. An annual of four or five hundred pages entirely devoted to play is now published in that country, where, in fact, most of the pedagogic movements of the past century have originated, and after careful investigation, the play ground movement was systematically undertaken there; and there is now in some German cities a law requiring that each school shall provide a minimum play space for each

pupil, which in Munich, for example, must be at least twenty-five square feet in area. In Berlin, there is a forty-acre play ground intended solely for small children. Play conferences are being held annually in the larger German cities and thousands of teachers are being taught to play games with the children.

France, on the other hand, has manifested much less interest in play. The games played by the children are mostly of a trivial nature, and there seems to be no literature on the subject. The superior morale of the German army, as evinced in the Franco-Prussian War, was the natural consequence of the better educational methods of the Germans. As the Duke of Wellington asserted that the battle of Waterloo was won on the football fields of Eton and Rugby, so one might say that the patriotic ardor of Jahn, who taught the Prussian soldiery gymnastic exercises from patriotic motives, bore fruit in the victory of Sedan. Yet in France, a strong attempt was made a few years ago to popularize athletic sports. Prizes were offered by various corporations and municipalities for excellence in various contests, in which thousands of the people, mostly I believe employees of the factories and shops, took a more or less conspicuous part.

In England, the home of manly sport, one finds many municipalities owning their football and cricket fields, just as they own a town hall, and many of the working men and boys spend their half holidays playing games. The public schools in that country are admirably supplied with playgrounds, and cricket and football are compulsory in these schools for all the scholars physically qualified to play, and, furthermore, the teachers are required to play with the pupils; and now in London the authorities declare their intention to have a playground within a quarter of a mile of every home.

In the United States there is an effort being made to replan our cities so as to make adequate provision for play for young and old. Our playgrounds are now absurdly inadequate. Until 1899, a section of New York City, containing 500,000 inhabitants, had no open space whatever for play. The movement toward bettering this condition of things is so vigorous and so general, thanks to the efforts of such philanthropists as Jacob Riis, and the results of what has already been accomplished in New York are so gratifying, that great and continued improvement may be confidently expected. The city now sets aside, we are told in the report of the United States Commissioner of Education, \$300,000 each year for the purchase of playgrounds, and \$1,000,000 a year for small parks. Unfortunately it will take \$100,000,000 to buy enough land to provide the 630,000 children now in the city with room enough to play in.

Chicago has over 73 acres of playgrounds; Philadelphia 110 acres; Brooklyn 40, and Boston, the most intellectual city in the country, has

the largest area of playgrounds, nearly 200 acres. In each of the new playgrounds of New York, which were opened in seven of the smaller parks in 1903, there were gymnastic and kindergarten instructors in charge. These are for children under fifteen; Chicago has five or six such playgrounds, and ten more were to be opened in 1903. The new municipal playground, in Seward Park in New York, is probably the best in the world. It cost the city \$2,500,000. There are from two to three thousand children playing there most of the time when the schools are not in session, and at 7 P. M. from 6,000 to 7,000 are there, practically every day. A philanthropist has offered to spend \$4,000,000 in laying out and equipping a playground, bathing pavilion and beach on Staten Island, and providing a steamboat to take a large number, probably a thousand, poor children from New York to the beach and back every day. So long ago as 1902 there were ten roof gardens provided in New York City, at each of which the average daily attendance was 2,000. There were besides twenty play centers and seven recreation piers. Swimming-baths were also provided and fifty swimming teachers. In Glasgow were the first municipal playgrounds, and be it observed in passing, this was one of the first cities in the world to adopt municipal ownership of public utilities.

As playgrounds are gradually being established all over the civilized world, so opportunities for proper personal cleanliness are gradually being provided for the humblest citizen. In Munich a public bath house has just been opened. A gift to the city from a private citizen. It cost \$500,000, twice as much as the complete gymnasium at Yale. Public baths have been opened in London and other foreign cities. In Boston, of the American cities, probably the best bathing facilities are provided for the common people. It is estimated that each inhabitant of the city may enjoy five baths a year, whereas in the densely crowded districts of New York, Baltimore and Chicago, the Department of Labor found only two to three per cent. of the houses supplied with baths in 1894. Now, however, in Seward Park in New York, and presumably in the other new parks, excellent public baths are provided in addition to a number of floating baths.

There has been a strange awakening in the Empire of China in these latter days; we can scarcely believe the reports that China is now turning to the light, and that the conservatism of centuries is at last yielding to the influence of modern ideas. But it is so. And one of the best evidences of real advance toward the liberation of man from the moral and physical bondage of generations is that an imperial edict exhorts "parents to refrain from binding their daughters' feet," and declares that men who wish to hold office must not have wives or

daughters whose feet are bound. At Peking a newspaper² for women has been established, edited by a Chinese woman; one of its objects is the teaching of hygiene. Another recent imperial edict forbids the smoking of opium in China.

The present world-wide agitation against child labor is another suggestive fact which points toward a physical millenium. Child labor laws have been very generally enacted. In New Zealand all employed women and children have been placed under strict legal protection. The strictest child labor law in the world probably has been enacted in that country.

In the new Japan, physical excellence is part of their religion; it is demanded by Bushido, their moral code, and by patriotism. The feeble of body among the Samurai will not marry. Dr. Griffis informs us in "The Mikado's Empire," that by means of physical reconstruction of the whole people, through improved hygienic and preventive measures against disease and wounds, Japan in 1904 has become a new nation. As compared with their status in 1870, they have been raised to the fifth power. At the same time, the soldiers have increased remarkably in stature, while the recruits in the English army have deteriorated in physique, owing presumably to intemperance and vicious living.

The Turners' societies in America are constantly growing in numbers and influence. Their first normal school of gymnastics was organized in 1861. Over sixty per cent. of their members enlisted in the Union armies, and the financial resources of the gymnastic societies and of the female auxiliaries were taxed to the utmost in aiding the families of their members who were in the army and in caring for the widows and orphans of those who had been killed. Every member of a *turnverein* is required to become a naturalized citizen of the United States. As Ling in Sweden and Jahn in Prussia organized their gymnastic societies from motives of patriotism, so, as we have just seen, the Turners in the United States were organized. At present they have 237 unions with about 40,000 members, and stand for all that is best in government, education, morals and good citizenship. The basis of their work is a sound physical education.

The growing interest in humaniculture can not truthfully be said to be due to a passing fashion. On the contrary, it is a part of a mighty movement, and like other great movements in human evolution, it is worthy of serious study. Not simply in its more obvious relations, but in its bearing upon other movements and other influences in human progress. As man is now advancing, in self discipline, in

²The circulation of journals devoted to health and hygiene has increased in this country until one of the best known is said to issue 300,000 copies each month.

charity, and in civic virtue, in short, as he is passing out of the age of individualism into that of fraternalism, evidence is abundant on every side that the body beautiful, the visible expression of a strong and lofty soul, shall no longer be neglected and its care and development left to chance or ignorance. Physical education and civic virtue, which is but an active demonstration of the love of one's fellows, are advancing with equal step. Charity, patience and courage are the attributes of the well-trained and vigorous physique, and these traits of character are daily becoming more common.

Instances similar to those appearing in this paper probably might be multiplied indefinitely, yet enough have been cited, it seems to me, to prove the contention that in nearly every quarter of the earth, pagan and Christian alike, are to be perceived unmistakable signs of the approach of a general "physical renaissance such as the world has only seen twice, or perhaps thrice, and which preceded the most brilliant periods in the intellectual history of mankind." In spite of the lamentations which we so often hear of the sordidness and vulgarity of modern life, of the brazen display of wealth and the venality of public men, there are not wanting many signs that the tide is setting in toward a higher and a nobler manhood and a purer, simpler and more wholesome life, and not the least of these signs is the evidence just cited, gathered from many different sources, that the physical conscience is again, after slumbering for 2,000 years, awaking and asserting itself, and will rule the world again as it did in ancient Greece.

If the coming man will listen to its voice it will lead him into a civilization that will surpass that of Greece by as much as the present age surpasses that of Pericles in the "solid progress of the sciences and their application to the useful arts."

PROBABILITY, THE FOUNDATION OF EUGENICS¹

BY FRANCIS GALTON, F.R.S.
LONDON

THE request so honorable to myself, to be the Herbert Spencer lecturer of this year, aroused a multitude of vivid recollections. Spencer's strong personality, his complete devotion to a self-imposed and life-long task, together with rare gleams of tenderness visible amidst a wilderness of abstract thought, have left a unique impression on my mind that years fail to weaken.

I do not propose to speak of his writings; they have been fully commented on elsewhere, but I desire to acknowledge my personal debt to him, which is large. It lies in what I gained through his readiness to discuss any ideas I happened to be full of at the time, with quick sympathy and keen criticism. It was his custom for many afternoons to spend an hour or two of rest in the old smoking room of the Athenæum Club, strolling into an adjoining compartment for a game of billiards when the table was free. Day after day on those afternoons I enjoyed brief talks with him, which were often of exceptional interest to myself. All that kind of comfort and pleasure has long ago passed from me. Among the many things of which age deprives us, I regret few more than the loss of contemporaries. When I was young I felt diffident in the presence of my seniors, partly owing to a sense that the ideas of the young can not be in complete sympathy with those of the old. Now that I myself am old it seems to me that my much younger friends keenly perceive the same difference, and I lose much of that outspoken criticism which is an invaluable help to all who investigate.

History of Eugenics

It must have surprised you as it did myself to find the new word "Eugenics" in the title both of the Boyle lecture, delivered in Oxford about a fortnight ago, and of this. It was an accident, not a deliberate concurrence, and I accept it as a happy omen. The field of eugenics is so wide that there is no need for myself, the second lecturer, to plant my feet in the footsteps of the first; on the contrary, it gives freedom by absolving me from saying much that had to be said in one way or another. I fully concur in the views so ably presented by my friend and co-adjutor Professor Karl Pearson, and am glad to be dispensed from further allusion to subjects that formed a large portion

¹ The Herbert Spencer lecture delivered at Oxford University on June 5, 1907.

of his lecture, on which he is a far better guide and an infinitely higher authority than myself.

In giving the following sketch of the history of eugenics I am obliged to be egotistical, because I kindled the feeble flame that struggled doubtfully for a time until it caught hold of adjacent stores of suitable material, and became a brisk fire, burning freely by itself, and again because I have had much to do with its progress quite recently.

The word "eugenics" was coined and used by me in my book "*Human Faculty*," published as long ago as 1883, which has long been out of print; it is, however, soon to be re-published in a cheap form. In it I emphasized the essential brotherhood of mankind, heredity being to my mind a very real thing; also the belief that we are born to act, and not to wait for help like able-bodied idlers, whining for doles. Individuals appear to me as finite detachments from an infinite ocean of being, temporarily endowed with executive powers. This is the only answer I can give to myself in reply to the perpetually recurring questions of "Why? whence? and whither?" The immediate "whither?" does not seem wholly dark, as some little information may be gleaned concerning the direction in which nature, so far as we know of it, is now moving. Namely, towards the evolution of mind, body and character in increasing energy and co-adaptation.

I have often wondered that the poem of Hyperion, by Keats—that magnificent torso of an incompleated work—has not been placed in the very forefront of past speculations on evolution. Keats is so thorough that he makes the very divinities to be its product. The earliest gods such as Coelus, born out of Chaos, are vague entities, they engender Saturn, Oceanus, Hyperion, and the Titan brood, who superseded them. These in their turn are ousted from dominion by their own issue, the Olympian Gods. A notable advance occurs at each successive stage in the quality of the divinities. When Hyperion, newly terrified by signs of impending overthrow, lies prostrate on the earth "his ancient mother, for some comfort yet," the voice of Coelus from the universal space, thus "whispered low and solemn in his ear . . . yet do thou strive for thou art capable . . . my life is but the life of winds and tides, no more than winds and tides can I prevail, but thou canst." I have quoted only disjointed fragments of this wonderful poem, enough to serve as a reminder to those who know it, but will add ten consecutive lines from the speech of the fallen Oceanus to his comrades, which give a summary of evolution as here described:

As Heaven and Earth are fairer, fairer far
Than Chaos and black Darkness, though once chiefs,
And as we show beyond that Heaven and Earth
In form and shape compact and beautiful,
In Will, in action free, companionship,

And thousand other signs of purer life;
 So on our heels a fresh perfection treads
 A power more strong in beauty, born of us
 And fated to excel us, as we pass
 In glory that old Darkness.

He ends with "this is the truth, and let it be your balm." The poem is a noble conception, founded on the crude cosmogony of the ancient Greeks.

The ideas have long held my fancy that we men may be the chief, and perhaps the only executives on earth. That we are detached on active service with, it may be only illusory, powers of free-will. Also that we are in some way accountable for our success or failure to further certain obscure ends, to be guessed as best we can. That though our instructions are obscure they are sufficiently clear to justify our interference with the pitiless course of nature, whenever it seems possible to attain the goal towards which it moves, by gentler and kindlier ways. I expressed these views as forcibly as I then could in the above-mentioned book, with especial reference to improving the racial qualities of mankind, in which the truest piety seems to me to reside in taking action, and not in submissive acquiescence to the routine of nature. It was thought impious at one time to attach lightning conductors to churches, as showing a want of trust in the tutelary care of the deity to whom they were dedicated; now I think most persons would be inclined to apply some contemptuous epithet to such as obstinately refused, on those grounds, to erect them.

The direct pursuit of studies in eugenics, as to what could practically be done, and the amount of change in racial qualities that could reasonably be anticipated, did not at first attract investigators. The idea of effecting an improvement in that direction was too much in advance of the march of popular imagination, so I had to wait. In the meantime I occupied myself with collateral problems, more especially with that of dealing measurably with faculties that are variously distributed in a large population. The results were published in my "Natural Inheritance" in 1889, and I shall have occasion to utilize some of them later on, in this very lecture. The publication of that book proved to be more timely than the former. The methods were greatly elaborated by Professor Karl Pearson, and applied by him to biometry. Professor Weldon of this university, whose untimely death is widely deplored, aided powerfully. A new science was thus created primarily on behalf of biometry, but equally applicable to eugenics, because their provinces overlap.

The publication of *Biometrika*, in which I took little more than a nominal part, appeared in 1901.

Being myself appointed Huxley lecturer before the Anthropological Institute in 1901 I took for my title "The Possible Improvement of

the Human Breed under the Existing Conditions of Law and Sentiment" (*Nature*, November 1, 1901, *Report of the Smithsonian Institution, Washington*, for the same year).

The next and a very important step towards eugenics was made by Professor Karl Pearson in his Huxley lecture of 1903 entitled "The Laws of Inheritance in Man" (*Biometrika*, Vol III.). It contains a most valuable compendium of work achieved and of objects in view; also the following passage (p. 159), which is preceded by forcible reasons for his conclusions:

We are ceasing as a nation to breed intelligence as we did fifty to a hundred years ago. The mentally better stock in the nation is not reproducing itself at the same rate as it did of old; the less able, and the less energetic are more fertile than the better stocks. No scheme of wider or more thorough education will bring up, in the scale of intelligence, hereditary weakness to the level of hereditary strength. The only remedy, if one be possible at all, is to alter the relative fertility of the good and the bad stocks in the community.

Again in 1904, having been asked by the newly-formed Sociological Society to contribute a memoir, I did so on "Eugenics, its Definition, Aim and Scope." This was followed up in 1905 by three memoirs, "Restrictions in Marriage," "Studies in National Eugenics" and "Eugenics as a Factor in Religion," which were published in the memoirs of that society with comments thereon by more than twenty different authorities (*Sociological Papers*, published for the Sociological Society (Macmillan), Vols. I. and II.). The subject of eugenics being thus formally launched, and the time appearing ripe, I offered a small endowment to the University of London to found a research fellowship on its behalf. The offer was cordially accepted, so eugenics gained the recognition of its importance by the University of London, and a home for its study in University College. Mr. Edgar Schuster, of this university, became research fellow in 1905, and I am much indebted to his care in nurturing the young undertaking and for the memoirs he has contributed, part of which must remain for a short time longer unpublished.

When the date for Mr. Schuster's retirement approached, it was advisable to utilize the experience so far gained in reorganizing the office. Professor Pearson and myself, in consultation with the authorities of the University of London, elaborated a scheme at the beginning of this year, which is a decided advance, and shows every sign of vitality and endurance. Mr. David Heron, a mathematical scholar of St. Andrews, is now a research fellow; Miss Ethel Elderton, who has done excellent and expert work from the beginning, is deservedly raised to the position of research scholar; and the partial services of a trained computer have been secured. An event of the highest importance to the future of the office is that Professor Karl Pearson has undertaken, at my urgent request, that general supervision of its work which advancing age and infirmities preclude me from giving. He

will, I trust, treat it much as an *annexe* to his adjacent biometric laboratory, for many studies in eugenics might, with equal propriety, be carried on in either of them, and the same methods of precise analysis which are due to the mathematical skill and untiring energy of Professor Pearson are used in both. The office now bears the name of the Eugenics Laboratory, and its temporary home is in 88 Gower Street. The phrase "national eugenics" is defined as "the study of agencies under social control that may improve or impair the racial qualities of future generations, either physically or mentally."

The laboratory has already begun to publish memoirs on its own account, and I now rest satisfied in the belief that, with a fair share of good luck, this young institution will prosper and grow into an important center of research.

Application of Theories of Probability to Eugenics.

Eugenics seeks for quantitative results. It is not contented with such vague words as "much" or "little," but endeavors to determine "how much" or "how little" in precise and trustworthy figures. A simple example will show the importance of this. Let us suppose a class of persons, called *A*, who are afflicted with some form and some specified degree of degeneracy, as inferred from personal observations, and from family history, and let class *B* consist of the offspring of *A*. We already know only too well that when the grade of *A* is very low, that of the average *B* will be below par and mischievous to the community, but how mischievous will it probably be? This question is of a familiar kind, easily to be answered when a sufficiency of facts have been collected. But a second question arises, What will be the trustworthiness of the forecast derived from averages when it is applied to individuals? This is a kind of question that is not familiar, and rarely taken into account, although it too could be answered easily as follows: The average mischief done by each *B* individual to the community may for brevity be called *M*: the mischiefs done by the several individuals differ more or less from *M* by amounts whose average may be called *D*. In other words *D* is the average amount of the individual deviations from *M*. *D* thus becomes the measure of untrustworthiness. The smaller *D* is, the more precise the forecast, and the stronger the justification for taking such drastic measures against the propagation of class *B* as would be consonant to the feelings if the forecast were known to be infallible. On the other hand, a large *D* signifies a corresponding degree of uncertainty, and a risk that might be faced without reproach through a sentiment akin to that expressed in the maxim "It is better that many guilty should escape than that one innocent person should suffer." But that is not the sentiment by which natural selection is guided, and it is dangerous to yield far to it.

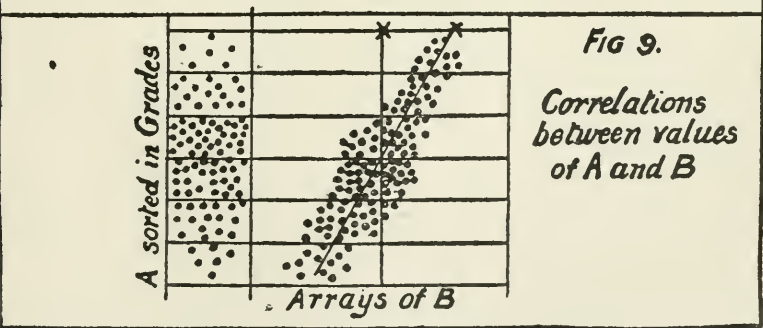
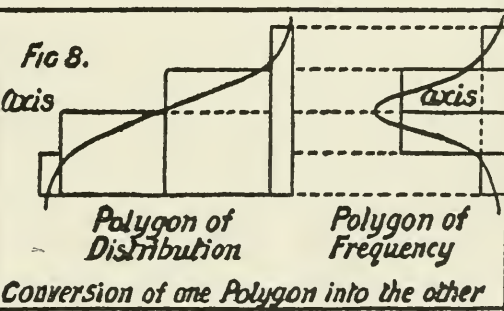
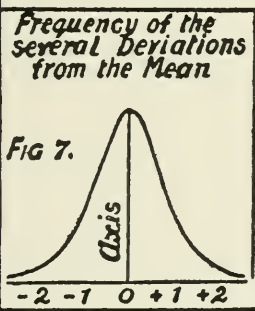
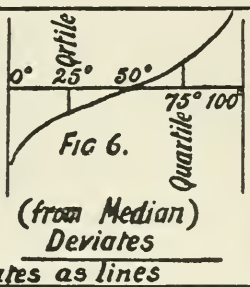
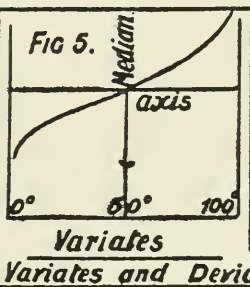
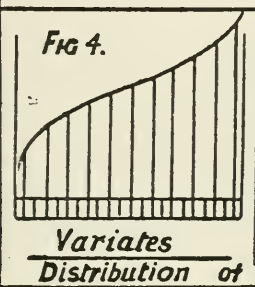
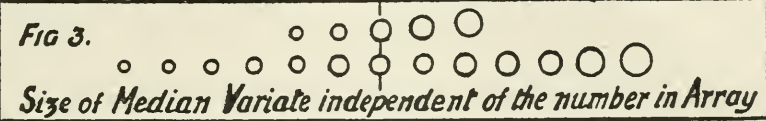
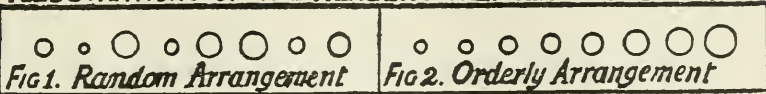
There can be no doubt that a thorough investigation of the kind described, even if confined to a single grade and to a single form of degeneracy, would be a serious undertaking. Masses of trustworthy material must be collected, usually with great difficulty, and be afterwards treated with skill and labor by methods that few at present are competent to employ. An extended investigation into the good or evil done to the state by the offspring of many different classes of persons, some of civic value, others the reverse, implies a huge volume of work sufficient to occupy eugenics laboratories for an indefinite time.

Object Lessons in the Methods of Biometry.

I propose now to speak of those fundamental principles of the laws of probability that are chiefly concerned in the newer methods of biometry, and consequently of eugenics. Most persons of ordinary education seem to know nothing about them, not even understanding their technical terms, much less appreciating the cogency of their results. This popular ignorance so obstructs the path of eugenics that I venture to tax your attention by proposing a method of partly dispelling it. Let me first say that no one can be more conscious than myself of the large amount of study that is required to qualify a man to deal adequately with the mathematical methods of biometry, or that any man can hope for much success in that direction unless he is possessed of appropriate faculties and a strong brain. On the other hand, I hold an opinion, likely at first sight to scandalize biometricians and which I must justify, that the fundamental ideas on which abstruse problems of probability are based admit of being so presented to any intelligent person as to be grasped by him, even though he be quite ignorant of mathematics. The conditions of doing so are that the lessons shall be as far as possible "object lessons," in which real objects shall be handled as in the kindergarten system, and simple operations performed and not only talked about. I am anxious to make myself so far understood that some teachers of science may be induced to elaborate the course that I present now only in outline. It seems to me suitably divisible into a course of five lessons of one hour each, which would be sufficient to introduce the learner into a new world of ideas, extraordinarily wide in their application. A proper notion of what is meant by correlation requires some knowledge of the principal features of variation, and will be the goal towards which the lessons lead.

To most persons variability implies something indefinite and capricious. They require to be taught that it, like Proteus in the old fable, can be seized, securely bound, and utilized; that it can be defined and measured. It was disregarded by the old methods of statistics, that concerned themselves solely with averages. The average amount of various measurable faculties or events in a multitude of

ILLUSTRATIONS OF THE HERBERT SPENCER LECTURE 1907.



persons was determined by simple methods, the individual variations being left out of account as too difficult to deal with. A population was treated by the old methods as a structureless atom, but the newer methods treat it as a compound unit. It will be a considerable intellectual gain to an otherwise educated person, to fully understand the way in which this can be done, and this and such like matters the proposed course of lessons is intended to make clear. It can not be expected that in the few available minutes more than an outline can be given here of what is intended to be conveyed in perhaps thirty-fold as much time with the aid of profuse illustrations by objects and diagrams. At the risk of being wearisome, it is, however, necessary to offer the following syllabus of what is proposed, for an outline of what teachers might fill in.

The object of the first lesson would be to explain and illustrate variability of size, weight, number, etc., by exhibiting samples of specimens that had been marshalled at random (Fig. 1), or arrayed in order of their magnitude (Fig. 2). Thus when variations of length were considered, objects of suitable size, such as chestnuts, acorns, hazelnuts, stones of wall fruit, might be arrayed as beads on a string. It will be shown that an "array" of variates of any kind falls into a continuous series. That each variate differs little from its neighbors about the middles of the arrays, but that such differences increase rapidly towards their extremities. Abundant illustration would be required, and much handling of specimens.

Arrays of variates of the same class strung together, differing considerably in the number of the objects they each contain, would be laid side by side and their middle-most variates or "medians" (Fig. 3) would be compared. It would be shown that as a rule the medians become very similar to one another when the numbers in the arrays are large. It must then be dogmatically explained that double accuracy usually accompanies a four-fold number, a treble accuracy a nine-fold number, and so on.

(This concludes the first lesson, during which the words and significations of variability, variate array, and median will have been learned.)

The second lesson is intended to give more precision to the idea of an array. The variates in any one of these strung loosely on a cord, should be disposed at equal distances apart in front of an equal number of compartments, like horses in the front of a row of stalls (Fig. 4), and their tops joined. There will always be one more side to the row of stalls than there are objects, otherwise a side of one of the extreme stalls would be wanting. Thus there are two ways of indicating the portion of a particular variate, either by its *serial number* as "first," "second," "third," or so on, or by *degrees* like those of a thermometer.

In the latter case the sides of the stalls serve as degrees, counting the first of them as 0° , making one more graduation than the number of objects, as should be. The difference between these two methods has to be made clear, and that while the serial position of the median object is always the same in any two arrays whatever be the number of variates, the serial positions of their subdivisions can not be the same, the ignored half interval at either end varying in width according to the number of variates, and becoming considerable when that number is small.

Lines of proportionate length will then be used drawn on a blackboard, and the limits of the array will be also drawn, at a half interval from either end. The base is then to be divided centesimally.

Next join the tops of the lines with a smooth curve, and wipe out everything except the curve, the limit at either side, and the centesimally divided base (Fig. 5). This figure forms a scheme of distribution of variates. Explain clearly that its shape is independent of the number of variates, so long as they are sufficiently numerous to secure statistical constancy.

Show numerous schemes of variates of different kinds, and remark on the prevalent family likeness between the bounding curves. (Words and meanings learnt—schemes of distribution, centesimal graduation of base.)

The third lesson passes from variates, measured upwards from the base, to deviates measured upwards or downwards from the median, and treated as positive or negative values accordingly (Fig. 6).

Draw a scheme of variates on the blackboard, and show that it consists of two parts; the median which represents a constant, and the curve which represents the variations from it. Draw a horizontal line from limit to limit, through the top of the median, to serve as axis to the curve. Divide the axis centesimally, and wipe out everything except curve, axis and limits. This forms a scheme of distribution of deviates. Draw ordinates from the axis to the curve at the twenty-fifth and seventy-fifth divisions. These are the "quartile" deviates.

At this stage the genesis of the theoretical normal curve might be briefly explained and the generality of its application; also some of its beautiful properties of reproduction. Many of the diagrams already shown would be again employed to show the prevalence of approximately normal distributions. Exceptions of strongly marked skew curves would be exhibited and their genesis briefly explained.

It will then be explained that while the ordinate at *any* specified centesimal division in two normal curves measures their relative variability, the quartile is commonly employed as the unit of variability under the almost grotesque name of "probable error," which is intended to signify that the length of any deviate in the system is as likely as

not to exceed or to fall short of it. This, by construction, is the case of either quartile.

(New words and meanings—scheme of distribution of deviates, axis, normal, skew, quartile and probable error.)

In the fourth lesson it has to be explained that the curve of normal distribution is not the direct result of calculation, neither does the formula that expresses it lend itself so freely to further calculation, as that of frequency. Their shapes differ; the first is an ogive, the second (Fig. 7) is bell-shaped. In the curve of frequency the derivations are reckoned from the mean of all the variates, and not from the median. Mean and median are the same in normal curves, but may differ much in others. Either curve can be transformed into the other, as is best exemplified by using a polygon (Fig. 8) instead of the curve, consisting of a series of rectangles differing in height by the same amounts, but having widths respectively representative of the frequencies of 1, 3, 3, 1. (This is one of those known as a binomial series, whose genesis might be briefly explained.) If these rectangles are arrayed in order of their widths, side by side, they become the equivalents of the ogival curve of distribution. Now if each of these latter rectangles be slid parallel to itself up to either limit, their bases will overlap and they become equivalent to the bell-shaped curve of frequency with its base vertical.

The curve of frequency contains no easily perceived unit of variability like the quartile of the curve of distribution. It is therefore not suited for and was not used as a first illustration, but the formula that expresses it is by far the more suitable of the two for calculation. Its unit of variability is what is called the "standard deviation," whose genesis will admit of illustration. How the calculations are made for finding its value is beyond the reach of the present lessons. The calculated ordinates of the normal curve must be accepted by the learner much as the time of day by his watch, though he be ignorant of the principles of its construction. Much more beyond his reach are the formulæ used to express quasi-normal and skew curves. They require a previous knowledge of rather advanced mathematics.

(New words and ideas—curve of frequency, standard deviation, mean, binomial series.)

The fifth and last lesson deals with the measurement of correlation, that is, with the closeness of the relation between any two systems whose variations are due partly to causes common to both, and partly to causes special to each. It applies to nearly every social relation, as to environment and health, social position and fertility, the kinship of parent to child, of uncle to nephew, etc. It may be mechanically illustrated by the movements of two pulleys with weights attached,

suspended from a cord held by one of the hands of three different persons, 1, 2, and 3. No. 2 holds the middle of the cord, one half of which then passes round one of the pulleys up to the hand of No. 1; the other half similarly round the other pulley up to the hand of No. 3. The hands of Nos. 1, 2 and 3 move up and down quite independently, but as the movements of both weights are simultaneously controlled in part by No. 2, they become "correlated."

The formation of a table of correlations on paper ruled in squares, is easily explained on the blackboard (Fig. 9). The pairs of correlated values A and B have to be expressed in units of their respective variabilities. They are then sorted into the squares of the paper,—vertically according to the magnitudes of A , horizontally according to those of B —, and the mean of each partial array of B values, corresponding to each grade of A , has to be determined. It is found theoretically that where variability is normal, the means of B lie practically in a straight line on the face of the table, and observation shows they do so in most other cases. It follows that the average deviation of a B value bears a constant ratio to the deviation of the corresponding A value. This ratio is called the "index of correlation," and is expressed by a single figure. For example: if the thigh-bones of many persons deviate "very much" from the usual length of the thigh-bones of their race, the average of the lengths of the corresponding arm-bones will differ "much," but not "very much," from the usual length of arm-bones, and the ratio between this "very much" and "much" is constant and in the same direction, whatever be the numerical value attached to the word "very much." Lastly, the trustworthiness of the index of correlation, when applied to individual cases, is readily calculable. When the closeness of correlation is absolute, it is expressed by the number 1.0, and by 0.0, when the correlation is nil.

(New words and ideas—correlation and index of correlation.)

This concludes what I have to say on these suggested object lessons. It will have been tedious to follow in its necessarily much compressed form but will serve, I trust, to convey its main purpose of showing that a very brief course of lessons, copiously illustrated by diagrams and objects to handle, would give an acceptable introduction to the newer methods employed in biometry and in eugenics. Further, that when read leisurely by experts in its printed form, it would give quite sufficient guidance for elaborating details.

Influence of Collective Truths upon Individual Conduct.

We have thus far been concerned with probability, determined by methods that take cognizance of variations, and yield exact results, thereby affording a solid foundation for action. But the stage on which

human action takes place is a superstructure into which emotion enters, we are guided on it less by certainty and by probability than by assurance to a greater or lesser degree. The word assurance is derived from *sure*, which itself is an abbreviation of *secure*, that is, of *se-cura*, or without misgiving. It is a contented attitude of mind largely dependent on custom, prejudice, or other unreasonable influences which reformers have to overcome, and some of which they are apt to utilize on their own behalf. Human nature is such that we rarely find our way by the pure light of reason, but while peering through spectacles furnished with colored and distorting glasses.

Locke seems to confound certainty with assurance in his forcible description of the way in which men are guided in their daily affairs ("Human Understanding," IV., 14, par. 1):

Man would be at a great loss if he had nothing to direct him but what has the certainty of true knowledge. For that being very short and scanty, he would be often utterly in the dark, and in most of the actions of his life, perfectly at a stand, had he nothing to guide him in the absence of clear and certain knowledge. He that will not eat till he has demonstration that it will nourish him, he that will not stir till he infallibly knows the business he goes about will succeed, will have little else to do but to sit still and perish.

A society may be considered as a highly complex organism, with a consciousness of its own, caring only for itself, establishing regulations and customs for its collective advantage, and creating a code of opinions to subserve that end. It is hard to over-rate its power over the individual in regard to any obvious particular on which it emphatically insists. I trust in some future time that one of those particulars will be the practise of eugenics. Otherwise the influence of collective truths on individual conduct is deplorably weak, as expressed by the lines:

For others' follies teach us not,
Nor much their wisdom teaches,
But chief of solid worth is what
Our own experience preaches.

Professor Westermarck, among many other remarks in which I fully concur, has aptly stated (*Sociological Papers*, published for the Sociological Society. Macmillan, 1906, Vol. II., p. 24), with reference to one obstacle which prevents individuals from perceiving the importance of eugenics, "the prevalent opinion that almost anybody is good enough to marry is chiefly due to the fact that in this case, cause and effect, marriage and the feebleness of the offspring, are so distant from each other that the *near-sighted eye* does not distinctly perceive the connection between them." (The Italics are mine.)

The enlightenment of individuals is a necessary preamble to practical eugenics, but social opinion is the tyrant by whose praise or blame the principles of eugenics may be expected hereafter to influence individual conduct. Public opinion may, however, be easily directed into different channels by opportune pressure. A common conviction

that change in the established order of some particular codes of conduct would be impossible, because of the shock that the idea of doing so gives to our present ideas, bears some resemblance to the conviction of lovers that their present sentiments will endure for ever. Conviction, which is that very assurance of which mention has just been made, is proved by reiterated experience to be a highly fallacious guide. Love is notoriously fickle in despite of the fervent and genuine protestations of lovers, and so is public opinion. I gave a list of extraordinary variations of the latter in respect to restrictions it enforced on the freedom of marriage, at various times and places (*Sociological Papers*, quoted above). Much could be added to that list, but I will not now discuss the effects of public opinion on such a serious question. I will take a much smaller instance which occurred before the time to which the recollections of most persons can now reach, but which I myself recall vividly. It is the simple matter of hair on the face of male adults. When I was young, it was an unpardonable offence for any English person other than a cavalry officer, or perhaps some one of high social rank, to wear a moustache. Foreigners did so and were tolerated, otherwise the assumption of a moustache was in popular opinion worse than wicked, for it was atrociously bad style. Then came the Crimean War and the winter of Balaclava, during which it was cruel to compel the infantry to shave themselves every morning. So their beards began to grow, and this broke a long established custom. On the return of the army to England the fashion of beards spread among the laity, but stopped short of the clergy. These, however, soon began to show dissatisfaction, they said the beard was a sign of manliness that ought not to be suppressed and so forth; and at length the moment arrived. A distinguished clergyman, happily still living, "bearded" his bishop on a critical occasion. The bishop yielded without protest, and forthwith hair began to sprout in a thousand pulpits where it had never appeared before within the memory of man.

It would be no small shock to public sentiment if our athletes in running public races were to strip themselves stark naked, yet that custom was rather suddenly introduced into Greece. Plato says (*Republic V.*, par. 452, Jowett's translation):

Not long ago the Greeks were of the opinion, which is still generally received among the barbarians, that the sight of a naked man was ridiculous and improper, and when first the Cretans and the Lacedæmonians introduced naked exercises, the wits of that day might have ridiculed them. . . .

Thucydides (*I. 6*) also refers to the same change as occurring "quite lately."

Public opinion is commonly far in advance of private morality, because society as a whole keenly appreciates acts that tend to its advantage, and condemns those that do not. It applauds acts of heroism

that perhaps not one of the applauders would be disposed to emulate. It is instructive to observe cases in which the benevolence of public opinion has outstripped that of the law—which, for example, takes no notice of such acts as are enshrined in the parable of the good Samaritan. A man on his journey was robbed, wounded, and left by the wayside. A priest and a Levite successively pass by and take no heed of him. A Samaritan follows, takes pity, binds his wounds, and bears him to a place of safety. Public opinion keenly condemns the priest and the Levite, and praises the Samaritan, but our criminal law is indifferent to such acts. It is most severe on misadventure due to the neglect of a definite duty, but careless about those due to absence of common philanthropy. Its callousness in this respect is painfully shown in the following quotations (Kenny, "Outlines of Criminal Law," 1902, p. 121, per Hawkins in Reg. v. Paine, *Times*, February 25, 1880):

If I saw a man who was not under my charge, taking up a tumbler of poison, I should not be guilty of any crime by not stopping him. I am under no legal obligation to protect a stranger.

That is probably what the priest and the Levite of the parable said to themselves.

A still more emphatic example is in the "Digest of Criminal Law," by Justice Sir James Stephen, 1887, p. 154. Reg. v. Smith, 2 C. and P., 449:

A sees B drowning and is able to help him by holding out his hand. A abstains from doing so in order that B may be drowned, and B is drowned. A has committed no offence.

It appears, from a footnote, that this case has been discussed in a striking manner by Lord Macaulay in his notes on the Indian Penal Code, which I have not yet been able to consult.

Enough has been written elsewhere by myself and others to show that whenever public opinion is strongly roused it will lead to action, however contradictory it may be to previous custom and sentiment. Considering that public opinion is guided by the sense of what best serves the interests of society as a whole, it is reasonable to expect that it will be strongly exerted in favor of eugenics when a sufficiency of evidence shall have been collected to make the truths on which it rests plain to all. That moment has not yet arrived. Enough is already known to those who have studied the question to leave no doubt in their minds about the general results, but not enough is quantitatively known to justify legislation or other action except in extreme cases. Continued studies will be required for some time to come, and the pace must not be hurried. When the desired fullness of information shall have been acquired, then, and not till then, will be the fit moment to proclaim a "Jihad," or Holy War against customs and prejudices that impair the physical and moral qualities of our race.

SOME LITTLE-KNOWN MEXICAN VOLCANOES

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WHILE the inhabitants of the United States were suffering from the heat of an unusual summer, the members of the International Geological Congress were making a study of the geology of the plateau region of Mexico and were enjoying the delightful climate of that country. Few regions of the world are more fascinating; the combination of vast volcanic peaks, broad arid plains, with their curious desert flora and a brilliant tropical sky, leaves an impression never to be forgotten.

It was in the midst of such interesting surroundings that during August, September and October, 1906, the International Congress of Geologists met, and, as a member, the writer had an opportunity to visit several of the Mexican volcanoes under especially favorable circumstances. In the first place, the guides to the various volcanoes were trained geologists of the Mexican Geological Survey, who had previously made a study of the regions to which they conducted the party. Moreover, the personnel of the visitors embraced geologists from Europe and America, who had investigated volcanoes in many parts of the world, and consequently, by way of comparison, were able to add a great deal of interesting information.

If you will look at a map of Mexico, you will notice that the names Volcano Colima, Nevado de Toluca and Valle de Santiago form the vertices of an obtuse triangle west of the City of Mexico. With these three points we will concern ourselves.

VOLCANO COLIMA

Volcano Colima, the most recently active volcano in Mexico, whose cloud-crowned summit can be seen for many miles along the Pacific coast, is situated almost due west of Mexico city and about fifty miles from the Pacific Ocean. It can be reached without much difficulty from the village of Zapotlan by a horseback journey of ten hours. On the ride one winds along the sharp divides which separate deep ravines, around the high Nevado, and finally reaches the foot of the cone from which the climb on foot must begin.

A more beautifully symmetrical volcanic cone than that of Colima, as viewed from the north, can hardly be imagined; the only feature breaking the symmetry being a secondary cone which arises from the northeast slope. The beauty of the cone is enhanced by the great clouds

of steam which, continually arising from the crater, either envelop the summit or, blown by the wind, stretch out into long white clouds.

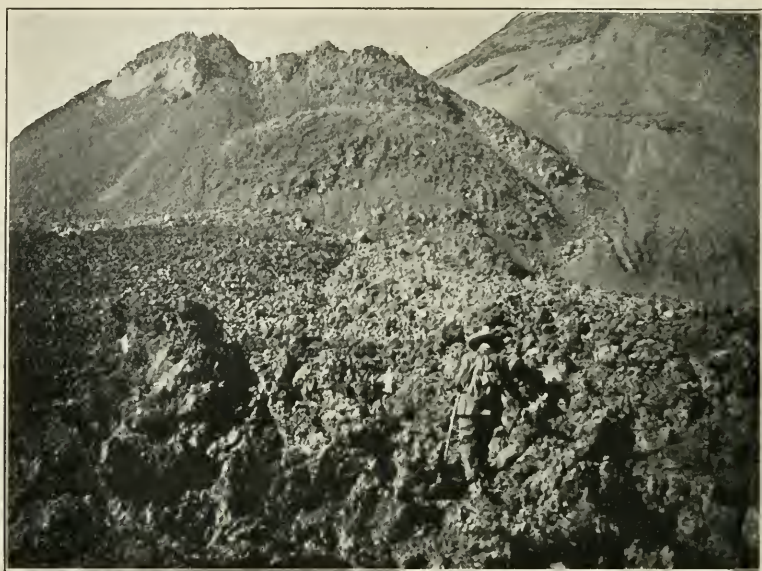


FIG. 1. SECONDARY CONE AND LAVA FLOW OF 1869.



FIG. 2. VOLCANO COLIMA WITH SECONDARY CONE.

The altitude of the principal cone is a little less than 12,600 feet above sea-level, while the top of the secondary cone is 780 feet lower.

The Lava Flow of 1869.—One of the chief difficulties in ascending Colima from the north side is the necessity of crossing the rough lava flow which was poured out from the secondary cone in 1869. The north side of this flow is very precipitous, as its highest point rises considerably above that of the central portion of the flow, thus forming a kind of wall on the north side. A more rapid cooling of the outer edge of



FIG. 3. THE NEVADO OF COLIMA.

the molten lava stream than that of the center formed this wall. As a result the sides hardened rapidly and consequently have an altitude about equal to that of the stream at its greatest height. The central portion, remaining hot for a longer time, flowed on after the lava had ceased to flow from the cone, and thus lowered its surface. In August, 1869, a month after the principal eruption, the lava is said to have flowed a little more than nine feet per day. The surface of this lava is as scoriaceous, irregular and crumbly (*aa*), as one can well imagine, but does not differ greatly from the *mal país* seen in other parts of Mexico. Because of this character, one is obliged to walk with the greatest care, stepping over or descending into fissures, climbing up or over irregular masses of scoriae. Indeed, the roughness of the lava hurts the hands and tears the shoes, and its treacherous character compels one to be on the alert at all times, which makes the work very exhausting.

Secondary Cone.—The secondary cone is composed of a compact though somewhat vesicular andesite with a steep slope. From this cone, as has been said, lava poured forth in 1869. There is no crater in the cone, although the summit is broken by three parallel fissures.

This fissuring may have been the result of shrinkage by cooling or it may have been due to a sinking of the lava in the cone. It seems probable that the secondary cone was formed as follows: Previous to the



FIG. 4. CRATER COLIMA, SEPTEMBER, 1906.

eruption of 1869, the pressure from below fissured the main cone. Through this fissure the lava welled up, flowing away as a lava stream. The stiffer and cooler lava, which was later forced up, failed to flow, and hardened to form the mound.

The Main Cone.—The ascent of the main cone is difficult because of the insecure footing afforded by the rolling ash and cinders and the steepness of the lava wherever it outcrops, as well as because of the altitude. The slope of the cone is between 35 and 39 degrees, although from a distance it appears to be much greater.

The Crater.—The rim of the crater is entire with the exception of a depression through which a lava stream flowed in 1885 and again in 1903. The view into the crater

from the higher portions of its rim is very impressive, even awe-inspiring. The slope on the outside of the rim is that of the volcano, but the inside drops precipitously to the bottom of the crater, a depth of more than 100 feet in many places. On account of the great quantities of steam which are continually rising,



FIG. 5. CROSS SECTION. SHOWING THE RELATIONS OF THE SECONDARY TO THE MAIN CONE.

it is only when an occasional gust of wind partially lifts the steam that one can get a glimpse of the floor of the crater. Descent into the crater by way of the breach in the side is comparatively easy and is attended with less danger than the view from the rim prophesied. The floor is covered with scoriaceous lava equaling, if not exceeding, in ruggedness that of the lava flow at the foot of the volcano. Steam with a tem-

perature of about 130 degrees Fahrenheit and sulphur dioxide are issuing from numerous fumaroles, some of which are lined with sulphur crystals. The crater is comparatively small, having a diameter of little over half a mile.

Recent Eruptions.—In 1877, 1884 and 1885 minor eruptions occurred. The last eruption of the volcano commenced in the month of February, 1903, and practically ceased in May of the same year. Since that time the only evidences of activity are the fumaroles from which issue large quantities of steam and other gases. During this eruption



FIG. 6. FLANK OF TOLUCA.

(1903) a lava stream flowed down the slope of the volcano in a north-west direction, but barely reached the foot of the volcano (see diagram), where it dammed a small stream, thus forming a shallow pond.

The accompanying diagrammatic cross-section of the volcano shows the relations of the secondary cone to the main cone, the position of the lava flow of 1869, the edge of this flow (*a*), the rim of the old crater (*b*), the lava flow of 1903, and the position and relative heights of Colima and the Nevado of Colima (which may have been the remnant of the rim of a great volcano long since destroyed). In the construction of this diagram, no attempt was made to draw the distances or heights to scale, but to bring out the salient points as clearly as possible.

VOLCANO TOLUCA

In the midst of the valley of Toluca, the Nevado of Toluca (Xinantecatl) towers almost 6,000 feet above the level of the plain and 14,833



FIG. 7. BARRANCA SHOWING STRATIFIED TUFF AND FOSSIL SOIL.

feet above the sea. It is called the Nevado, because usually its summit is white with snow. This volcano is isolated, being surrounded at some distance by volcanoes which have formed by the accumulation of their ash and lava an almost enclosed basin. It is one of the few high volcanoes of the world that can be ascended with ease, since it is possible to make the journey to and into the crater on horseback in four or five hours. Because of the ease with which it may be climbed the ascent has been made by a number of persons, the first of whom was the great geographer and traveler Humboldt, who reached the crater in 1803.

General Description.—Volcano Toluca is underlaid by calcareous rocks of Cretaceous age. The great mass of the volcano is composed of many layers of ash of varying degrees of thickness which conform quite closely to the slope. These layers of ash were apparently formed partly by the ash which rained down during the eruptions and partly by that which was carried down by streamlets and to a considerable extent in sheets during heavy rains. The accompanying photograph shows the stratified character of the slope and also a stratum of fossil soil, which in several of the "barrancas" or dry ravines is seen to be of considerable thickness. From this evidence it is fair to conclude that the last eruptions were preceded by a long period of inactivity, during which a large quantity of organic material was mixed with the weathered ash. Toluca has not been in eruption within historic times and at present there are no signs of activity, even secondary effects, such as fumaroles of steam and sulphur dioxide, being absent.

To watch the change in vegetation from the plain to the summit of the mountain is a constant pleasure. On the dry plain cactus and other desert plants are common, but on the flanks of the mountain pines begin and many bright-colored flowers. These, as one continues the ascent, become shorter and more stunted, until in the crater the flower blossoms an inch or thereabouts from the ground instead of one or two feet from the ground, as is the case lower down. On the highest portions of the rim vegetation is almost lacking.

The Crater.—The crater of the volcano is somewhat elliptical in form, being a little more than a mile in its longest diameter and about a third of a mile in its shortest. The crater rim is complete on all sides, but is low on the side through which entrance is made. In the bottom of the crater and 1,000 feet below the highest portion of the rim are two beautifully clear lakes, the larger of which is almost one fifth of a mile in diameter and has a maximum depth of thirty feet. These two lakes are separated by a dome of compact andesite of considerable height (see illustration). This dome is of especial interest, because of its bearings upon the origin of the Mt. Pelée spike. There seems to be little doubt, as T. Flores points out, that it is composed of the lava which was forced up and out of the vent after the last eruption and which now closes it and stands above the floor of the crater.

Comparison with Mt. Pelée.—It was suggested by Dr. E. O. Hovey that the Pelée plug was formed in this way also, *i. e.*, that instead of a solid mass of lava being pushed up bodily, as Heilprin believed, very



FIG. 8. CRATER OF TOLUCA, SHOWING LAKE AND ANDESITE CONE.

stiff lava, being forced from the vent after the last eruption, hardened into a high mound. In the case of Pelée the shape of the mound was modified by a splitting off of the lava along vertical planes, which produced the unique "spike" of that volcano.

Age.—A comparison of this volcano with others in Mexico has led Ordoñez to state that it probably made its appearance during Pliocene times.

CINDER CONES OF VALLE DE SANTIAGO

Cinder cones a few hundred feet in height are common objects in the central volcanic plateau of Mexico. Many of these may be seen in the basin in which the City of Mexico is situated, where the lower flanks of the higher volcanoes meet the plain. Near Toluca excellent examples occur. Because of the smallness of these cones as compared with the volcanoes near whose base they rise they are likely to be overlooked on



FIG. 9. CRATER LAKE AND CINDER CONE, VALLE DE SANTIAGO, MEXICO.

account of the overshadowing effect of the former. This is not true of the group of cinder cones, situated near the city Valle de Santiago, which are scattered about the valley some distance from the higher volcanoes, and which are, consequently, very conspicuous, their symmetrical truncated cones being the most marked features of the landscape.

This group of eleven craters occupies an area roughly circular in outline, one diameter of which is about six miles. Because of the fact that the valley of Santiago is a dry plain, the presence of lakes of pure water in four of the craters is unexpected. The clear blue

water of the lakes with their settings of green cultivated fields which cover the inner slopes of the craters are most beautiful objects.

The existence of these lakes is due to the fact that their bottoms are below the levels of underground water. All these crater lakes are at practically the same level, a condition which is due to the fact that the volcanic material in which they rest and of which the plain is composed is extremely porous, which permits the free circulation of the water. The craters of the majority of the cones were partially filled with lava which poured out quietly after the explosions which formed them had ceased. In some cases they were filled until their bottoms were above the level of underground water and are consequently dry; in others there was either no subsequent outpouring of lava or the quantity was very limited, in which case the cavity remained below the level of underground water and a lake resulted. The diameter of the craters vary in size from that of Solis (1,500 feet)—which was apparently produced by the sinking of the crust—to the largest, which is more than a mile in diameter. The craters are not all perfect; some are entire, while others are broken by one or two subsequent craters of explosion. In one of these breeched craters three small cones rise from the bottom, the material of which is apparently being used in the city for constructional purposes.

The plain upon which the craters rest is underlaid by one or more strata of basaltic lava which evidently flowed from the neighboring mountains and which may be seen near the water level of the lakes and in ravines which have been deeply cut by streams. Since neither this stratum nor the strata of basaltic lava are disturbed by being domed up or bent to any extent, it seems safe to conclude that the explosions forming the craters must have been near the surface and very local, otherwise the strata overlying the plain at that place would have been more or less bent.

The cones are made up in some cases of volcanic ash of various degrees of fineness, in others of volcanic breccia. The slopes are those which are normally made by such materials.

Because of the fact that craters of explosion in other parts of Mexico—Puebla, Mexico City, here in Valle de Santiago, and elsewhere in the republic—arise from a plain or a more or less enclosed basin which is full of water at a comparatively shallow depth, Ordoñez suggests that superficial water may have had a share in the production of the explosions.

Such are a few of the points of interest on the volcanic plateau of Mexico, a region which, interesting because of its scenery and climate, fascinating because of its romantic history, is to the geologist a volume which when studied will explain many points that are now a matter of speculation.

THE PROGRESS OF SCIENCE

DOES THE SPEED OF LIGHT IN
SPACE DEPEND UPON ITS
WAVE-LENGTH?

WHEN a beam of light comes through a prism of glass or a raindrop it is dispersed into a band of vivid colors, each denoting a particular wave-length. Though all these wave-lengths travel together in the air they part company in the glass or the water because there they no longer possess the same speed. The long waves, which produce the sensation of red, travel faster than the short, or violet waves.

Whether all wave-lengths really do travel with the same speed in air has not always been a matter of a single opinion. Lorenz and Ketteler both have found that the index of refraction for air differs by some seven parts in a million according to which end of the spectrum is employed. This means a proportionate difference in the speed of light in air for the long and for the short waves. More than a quarter of a century ago Young and Forbes, using Fizeau's method, seemed to find that the speed of the blue waves in air was 1.8 per cent. greater than that of the red ones. This result was threshed over by Lord Rayleigh, who pointed out serious objections to accepting their results. When Michelson was determining the speed of light, he paid especial attention to this question. When white light and red light were compared not the slightest trace of difference in their speeds could be detected. We may, therefore, rest assured that all waves of the visible spectrum travel with practically the same speed in air.

Now how is it in a vacuum, especially in that vast vacuum, interstellar space? If we begin by limiting our observations to our own solar system,

it has been noticed that when one of its satellites goes behind Jupiter its color is just the same as when it emerges. Suppose that Young and Forbes were right and that the blue rays do travel faster than the red rays. Then when the satellite is behind the planet so that it can send no more light to the earth, the train of waves which it emitted before its eclipse, still pursues its journey toward us. If the blue waves outrun the red waves, it will be the latter which give us our last glimpse of the satellite. At disappearance it should then appear red. Similarly upon emergence the blue should be the first waves to reach the eye, but no such difference of color upon eclipse and emergence is seen. Hence we may conclude that all waves of the visible spectrum travel in space with the same speed. It is, however, well to bear in mind that the universe is larger than the solar system and that the visible spectrum by no means includes all known radiation.

In 1859 Uriah A. Borden deposited with the Franklin Institute of Philadelphia one thousand dollars to be awarded as a premium to "any resident of North America who shall determine by experiment whether all rays of light, and other physical rays, are or are not transmitted with the same velocity." This problem was restated by the board of managers thus: "Whether or not all rays in the spectrum known at the time the offer was made, namely, March 23, 1859, and comprised between the lowest frequency known thermal rays in the infra-red, and the highest frequency known rays in the ultra-violet . . . travel through free space with the same velocity."

Dr. Paul R. Heyl, of the Central

High School of Philadelphia, has solved one part of this problem. He has shown that the ultra-violet waves and the waves of the visible spectrum travel with the same velocity. For this the Franklin Institute has awarded to him one thousand dollars of the accumulated fund. There has been no lack of applications for the premium, but no portion of it has ever before been awarded. The investigating committee, consisting of Mr. Hugo Bilgram, mechanical engineer; Professor A. W. Goodspeed, of the University of Pennsylvania, and Dr. G. F. Stradling, of the Northeast Manual Training High School of Philadelphia, were unanimous in their favorable opinion.

The star Algol, or β Persei, is a spectroscopic binary, that is, a study of its light shows that part of the time the star is approaching the earth and part of the time receding from it. Moreover, every 69 hours it grows less bright, only to regain its rank as a star of the second magnitude after the lapse of about 7 hours. The simplest explanation of these erratic performances is that there are two bodies, one luminous, the other opaque, revolving around their common center of mass. The dimming of brightness occurs when the opaque body gets between the earth and the luminous body. Their diameters, orbital velocities and masses have been calculated and also the distance their centers are apart.

The remoteness of Algol—it takes light 30 years to come thence to the earth—as well as its change of brightness caused it to be selected by Dr. Heyl for his investigation. In brief his method was this. He obtained records of the change of brightness of the star by photographing it at intervals in ultra-violet light produced by a transparent diffraction grating. The variation as judged by the eye was already known. If the ultra-violet waves travel faster than those belonging to the visible spectrum there would be a shifting of the time of least brightness of the

image. A comparison of the two cycles of change however shows that there can not be a greater difference between the speed of the ultra-violet light and that of the visible spectrum of more than one part in 250,000.

There seems to have been no previous determination of the speed of ultra-violet waves in a vacuum. Dr. Heyl's result, in substance that the two kinds of waves do not differ in speed by more than 1 km. per second, is of high value. To be sure it has been assumed for a long time that no such difference existed, but an experimental proof is a very different thing from mere extrapolation.

The work was conducted with the 8-inch equatorial of the Central High School and extended over a period of two years. The times when the variation of Algol occurred at a suitable time of day and under appropriate conditions of the sky were rare.

As yet there seems to be no experimental demonstration that the infra-red rays and those of the visible spectrum travel in space with the same speed. As far back as 1842 Wrede believed he had shown that the two speeds were different, but his work was subject to error. The method of Dr. Heyl does not lend itself to the settlement of this second part of the problem, since the infra-red rays have little effect upon a photographic plate. Let us hope that some physicist may devise an appropriate method and thus remove this gap in our knowledge of the velocity of radiation—incidentally obtaining another portion of the Boyden premium.

THE DUKE OF ARGYLE

THE autobiography and memoirs of the late Duke of Argyle, edited by his wife, have lately been published in two large volumes. Perhaps most men of science, on being asked offhand for an estimate of the duke, would reply that he was an amiable dilettante, with more enthusiasm than knowledge. In a way, this is correct enough; but given



*George Douglas, 8th Duke of Argyll K.G.
1898*

without qualification, it does him a great injustice. He was, throughout his life, an earnest, sincere and industrious man, much interested in the advancement of his fellows and the cultivation of his own mind. Inheriting an enormous estate, and taking a most prominent part in the politics of his time, he bore on his shoulders as great a burden as a man might care to lift, without taking time and energy for scientific work. It is impossible to say what he might have done, had he devoted himself mainly to some single branch of science or literature, but one may readily believe that it would in no

wise have equalled his actual achievement as a versatile man of affairs. He was not a genius, in the ordinary acceptance of the term; but he was one of those thoroughly useful citizens who serve to hold together the diverse elements of human society. In this sense, he was a duke in fact as well as in name, and an aristocracy so typified is not without a certain justification even from our democratic point of view.

Many naturalists are familiar—and some no less tired than familiar—with the duke's controversial writings on semi-metaphysical questions relating to evolution. Fewer, we imagine, know

how enthusiastically he watched the birds and other living things on his estate, and how graphically and accurately he could describe them. The following, taken from a letter to Lord Litford, should endear him to every ornithologist: "Anent the dipper, I need not say how I agree with you in loving them. I have three salmon streams in my estates which they haunt. I never allow one to be shot. We have many pairs, but they never seem to increase much. As to their propensities, I have had ocular demonstration that they eat fish, and that greedily. Twice I have seen a dipper with a fish in his bill—one was a trout or salmon fry, the other was a small flounder. This was in the seaport of the river Aray below my house. The flounder was, of course, a small one, but it was as broad as the white waistcoat of its devourer. I had a good glass, and saw the dipper emerge with the little flounder in his bill. He then took it to a large boulder stone near the bank, and began beating it to death against the stone. Twice it slipped off into the stream, and each time it was firmly pursued and brought back to the block! All aquatic piscivorous birds seem to have a way of doubling and folding up the flat fishes they catch so as to get them down, but I did not see the feat performed in the present case."

The following good story is told in another part of the same letter: "I bought two 'civette' (small owls) in Rome, and took them in a cage with me home. We travelled with Gladstone. He was immensely captivated by the brilliant yellow eyes of the birds. They fastened them on Gladstone's brown eyes with a fixed stare, and he took it into his head to try if he could stare them out of countenance. He continued to joke all the way from Rome to near Perugia, and at last the owls gave it up and looked away. He seemed as delighted as if he had won a great Parliamentary triumph." This is dated 1896. His first letter on birds, so far

as the biography shows, was written in 1837—and the interest did not flag in the long interval.

SCIENTIFIC ITEMS

WE record with regret the deaths of Professor Alfred Newton, F.R.S., who held the chair of zoology and comparative anatomy at Cambridge; of Dr. Edward John Routh, F.R.S., the mathematician, of the University of Cambridge; of Dr. Maxwell Tylden Masters, F.R.S., the English botanist and horticulturist; of Dr. Alexander Stewart Herschel, F.R.S., honorary professor of physics at the Durham College of Science; of Sir Dietrich Brandis, F.R.S., inspector general of the forests of India; of Professor Kuno Fischer, professor of philosophy at Heidelberg; of Henry G. Hanks, at one time state geologist of California, and of Mrs. Elizabeth Cabot Cary Agassiz, who in 1850 married Louis Agassiz, with whose work she was intimately associated, and whose life she wrote.

THE council of the British Association for the Advancement of Science has nominated Mr. Francis Darwin, F.R.S., foreign secretary to the Royal Society, author of important papers on physiological botany and of the 'Life and Letters of Charles Darwin,' to be president of the meeting next year, when, for the fourth time, the association will assemble in Dublin.—M. de Lapparent, professor of mineralogy and geology at Paris, has been elected permanent secretary of the Paris Academy of Sciences in succession to the late M. Berthelot.—On the occasion of the celebration of the bicentenary of the birth of Linnaeus, the Linnean gold medal of the Royal Swedish Academy was awarded to Sir Joseph Hooker.—A portrait of President Eliot by Mr. John P. Sargent has been unveiled in the Harvard Union.

DR. E. H. SELLARDS, for three years geologist and zoologist to the Florida University, has been appointed state geologist of Florida by Governor Brow-

ard.—Dr. E. A. Ruddiman, professor of materia medica and pharmacy at Vanderbilt University, Nashville, has been appointed chief food and drug inspector of the Department of Agriculture.—Dr. Frederick L. Dunlap, instructor in the University of Michigan, has been appointed associate chemist in the Bureau of Chemistry, and will be a member of the board of food and drug inspection.

AN Italian Association for the Advancement of Science, proposed at Milan last year, has now taken form. The first meeting will be held at Parma in September next, when it is hoped

that the sister associations of Europe and America will send delegates.

MRS. RUSSELL SAGE has given the sum of \$300,000 to found what will be known as the Russell Sage Institute of Pathology as an adjunct to the City Hospital on Blackwell's Island.—Dr. Lawrence F. Flick, director of the Phipps Institute, Philadelphia, and chairman of the committee on the International Congress of Tuberculosis, which is to be held in Washington in the fall of 1908, announces that he has received \$35,000 in subscriptions to a fund of \$100,000 which he is raising to meet the necessary expenses.

THE POPULAR SCIENCE MONTHLY

SEPTEMBER, 1907

THE PROBLEM OF AGE, GROWTH AND DEATH

BY CHARLES SEDGWICK MINOT, LL.D., D.Sc.

JAMES STILLMAN PROFESSOR OF COMPARATIVE ANATOMY IN THE
HARVARD MEDICAL SCHOOL

III. THE RATE OF GROWTH

Ladies and Gentlemen: In the first of the lectures, I described those grosser characteristics of old age, which we ourselves can readily distinguish, or which an anatomical study of the body reveals to us. In the second lecture I spoke of the microscopic alterations which occur in the body as it changes from youth to old age. But besides the changes, which we have already reviewed, there are those others, very conspicuous and somewhat known to us all, which we gather together under the comprehensive term of *growth*. It is growth which I shall ask you to study with me this evening, and I shall hope, by the aid of our study, to reinforce in your minds the conclusion which I have already indicated, that the early period of life is a period of rapid decline, and that the late period of life is one of slow decline.

In order to study growth accurately, it is desirable, of course, to measure it, but since we are concerned with the general problem of growth, we wish no partial measure, such as that of the height alone would be. And indeed, if we take any such partial measure, how could we compare different forms with one another? The height of a horse is not comparable to that of a man; the height of a caterpillar is not comparable to that of any vertebrate. Naturally, therefore, we take to measuring the weight, which represents the total mass of the living body, and enables us at least with some degree of accuracy to compare animals of different sorts with one another. Now in studying this question of the increase of weight in animals, as their age increases, it is obviously desirable to eliminate from our experiments all disturbing factors which might affect the rate of growth or cause it to assume irregularities which are not inherent either in the organiza-

tion of the animal or in the changes age produces. The animals which belong to the vertebrate sub-kingdom, of which we ourselves are members, can be grouped in two large divisions according to the natural temperature of their bodies. The lower vertebrates, the fishes, frogs and their kin, are animals which depend for their body temperature more or less on the medium in which they live. The other division of vertebrate animals, which includes all the higher forms, are so organized that they have within certain limits the power of regulating their own body temperature. Now it is easily to be observed—and any one who has made observations upon the growth of animals can confirm this—that animals otherwise alike will grow at different speeds at different temperatures.

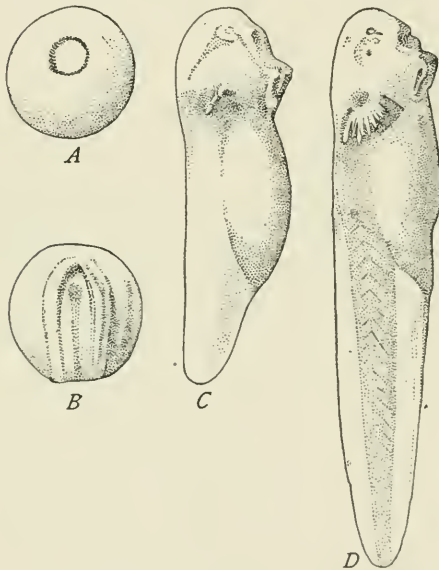


FIG. 19. FOUR TADPOLES OF THE EUROPEAN FROG *Rana fusca*. After Oskar Hertwig. The four animals are all of the same age (three days) and raised from the same batch of eggs, but have been kept at different temperatures.

A at 11.5° Centigrade.

B at 15.0° Centigrade.

C " 20.0° " "

D " 24.0° " "

There are animals, like the frogs and salamanders, which will live at a very considerable range of temperature and thrive, apparently. No ultimate injury is done to them by a change of their bodily temperature. Here we have a picture of four young tadpoles, all of which are exactly three days old. The first of these has been kept at a temperature not much above freezing. The fourth, at a temperature of about 24 degrees centigrade; the other two at temperatures between. They are all descendants from the same batch of frogs' eggs, and you can see readily that the first one is still

essentially nothing but an egg. The second one, which has had a little higher temperature, already shows some traces of organization, and those familiar with the development of these animals can see in the markings upon the surface the first indications of the differentiation of the nervous system. The third has been kept at a considerably warmer temperature, and is now obviously a young tadpole; here are the eyes, the rudimentary gills, the tail, etc. While the fourth tadpole, which was maintained at the best temperature for the growth of these animals, has advanced enormously in its development. Obviously, should we make experiments upon animals of this class it would be

necessary to keep them at a uniform temperature, if we wished to study their rate of development, and that is, for very practical reasons, extremely difficult and unsatisfactory. Far better it has seemed for our study of growth to turn to those animals which regulate their own temperature. This, accordingly, I have done, and the animal chosen for these studies was the guinea-pig, a creature which offers for such investigations certain definite advantages. It is easily kept; it is apt to remain, with proper care, in good health. Its food is obtainable at

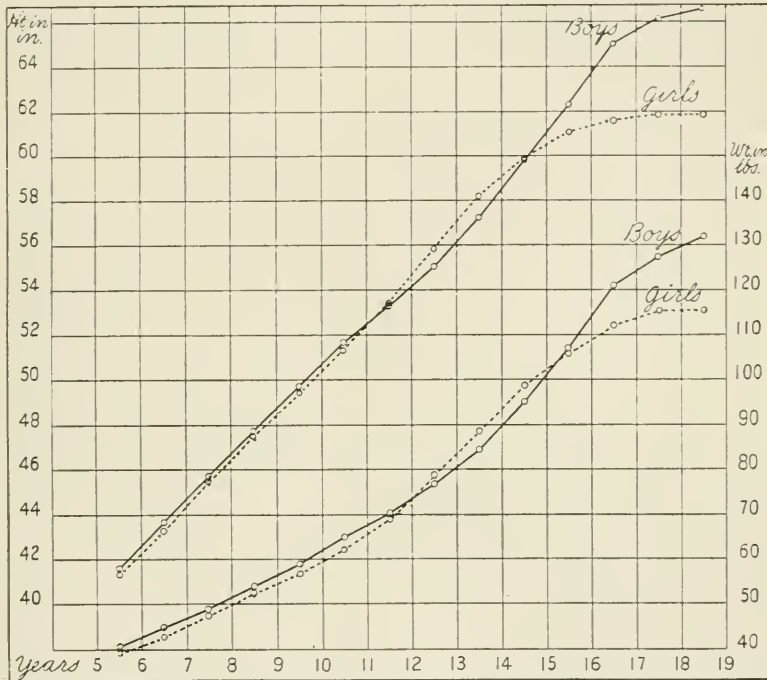


FIG. 20. CURVES SHOWING THE GROWTH OF BOSTON SCHOOL CHILDREN IN HEIGHT AND WEIGHT. After H. P. Bowditch.

all seasons of the year, in great abundance, and at small expense. The animals themselves being of moderate size do not, of course, require such extraordinary amounts of food as the large animals, should we experiment with them. Accordingly with guinea-pigs I began making, years ago, a long series of records, taking from day to day, later from week to week, and then, as the animals grew older, month by month, the weight of recorded individuals. There was thus obtained a body of statistics which rendered it possible to form some idea of the rapidity of growth of this species of mammal.

Now in regard to the rapidity of growth, it is necessary that we form clearer notions than perhaps you started out with when you came into the hall this evening. I will ask for the next of our pictures on the screen, where we shall see illustrated to us older methods of

recording the progressive growth of animals. This is a chart taken from the records of my friend, Dr. Henry P. Bowditch, showing the growth of school children in Boston. Here we have, in the lower part of the figure, the two curves of growth in weight. The upper curve is the weight of boys. We can follow it back through the succession of years down to the age of five and one half years, when the records begin. The child weighs, as you see, a little over forty pounds at that time. When the boy reaches the age of eighteen and one half years, he approaches the adult size, and weighs well over 130 pounds. Here then we see growth represented to us in the old way, the progressive increase of the animal as it goes along through the succession of years. Now this is a way which records the actual facts satisfactorily. It shows the progressive changes of weight as they really occur; but it does not give us a correct impression of the *rate* of growth. Concerning the rate of growth, some more definite notion must be established in our minds before we can be said to have an adequate conception of the meaning of that term. It is from the study of the statistics of the guinea-pigs, and of other animals, which I have since had an opportunity of experimenting with, that we get indeed a clearer insight as to what the rate of growth really is and really means.

I should like to pause a moment to say that when I first published a paper upon the subject of growth, it, fortunately for me, interested the late Dr. Benjamin Gould. The experiments which I had made and recorded in that first publication came to a sudden end, owing to a disaster for which I myself was personally not responsible, by which practically my entire stock of animals was suddenly destroyed. Dr. Gould, after consulting with me, proposed that I should have further aid from the National Academy of Sciences, and through his intervention I obtained a grant from the Bache fund of the academy. That liberal grant enabled me to continue these researches, and this is the first comprehensive presentation of my results which I have attempted. In this and the subsequent lectures, I hope that enough of what is new in scientific conclusions may appear to make those to whose generosity I am indebted feel that it has been worthily applied. I can not let such an occasion as this pass by without expressing publicly my gratitude to Dr. Gould for his encouragement and support at a time when I most keenly appreciated it.

If animals grow, that which grows is of course the actual substance of the animal. Now we might say that given so much substance there should be equal speed of growth, and we should expect, possibly, to find that the speed would be more or less constant. I can perhaps illustrate my meaning more clearly, and briefly render it distinct in your minds, by saying that if the rate of growth, as I conceive it, should remain constant, it would take an animal at every age just the same length of time to add ten per cent. to its weight; it would not be a

question whether a baby grew an ounce in a certain length of time, and a boy a pound in the same time, for the pound might not be the same percentage of advance to the boy that the ounce would be to the baby. In reality with an advance of an ounce the baby might be growing faster than the older boy with the addition of the pound.

In the next slide which we are to have thrown upon the screen we have my method of measuring rate of growth illustrated graphically. There is here a curve which represents the rate of growth of male guinea-pigs. The figures at the bottom indicate the age of the animals in days. When guinea-pigs are born, they are very far advanced in development, and the act of birth seems to be a physiological

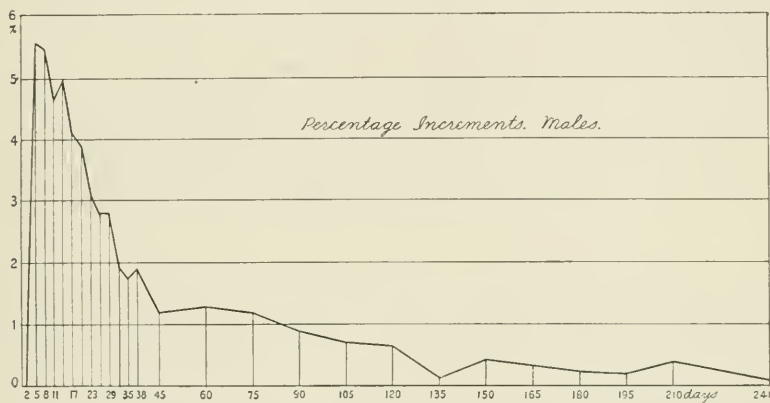


FIG. 21. CURVE SHOWING THE DAILY PERCENTAGE INCREMENTS IN WEIGHT OF MALE GUINEA PIGS.

shock from which the organism suffers, and there is a lessening of the power of growth immediately after birth. But in two or three days the young are fully recovered, and after that restoration they can add over five per cent. to their weight in a single day. But by the time they are 17 days old, as represented by this line, they can add only four per cent., and by the time they are 24 days old, less than two per cent.; at 45 barely over one per cent.; at 70 still over one per cent.; at 90 less; at 160 less; and towards the end the curve continues dropping off, coming gradually nearer and nearer to zero, to which it closely approximates at the age of 240 days. In about a year, the guinea-pig attains nearly its full size. You notice that this curve is somewhat irregular. Such is very apt to be the result from statistics when the number of observations is not very large. It means simply that there was not a sufficiently large number of animals measured to give an absolutely even and regular set of averages. But the general course of the curve is very instructive. In the earlier condition of the young guinea-pig there is a rapid decline; in the later, a slow decline.

The change from rapid to slow decline is not sudden, but gradual, as you see by the general character of this curve.

In the next slide we can see immediately that what I have asserted as true of the male is equally true of the female, although the values

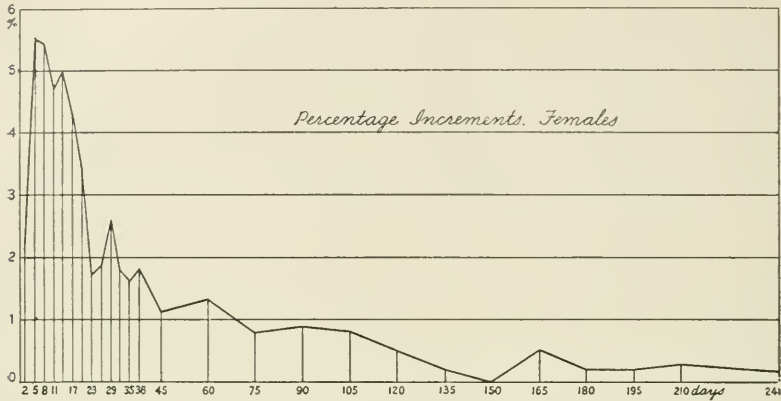


FIG. 22. CURVE SHOWING THE DAILY PERCENTAGE INCREMENTS IN WEIGHT OF FEMALE GUINEA-PIGS.

which we have differ slightly in the two sexes, and there are accidental but not significant variations in this curve as in the first. Here also we observe at once an early period of rapid decline in which the rate of growth is going down and down—a period of slight decline in which, to be sure, it is going down still, but with diminished rapidity.

There is another method by which we can represent this change

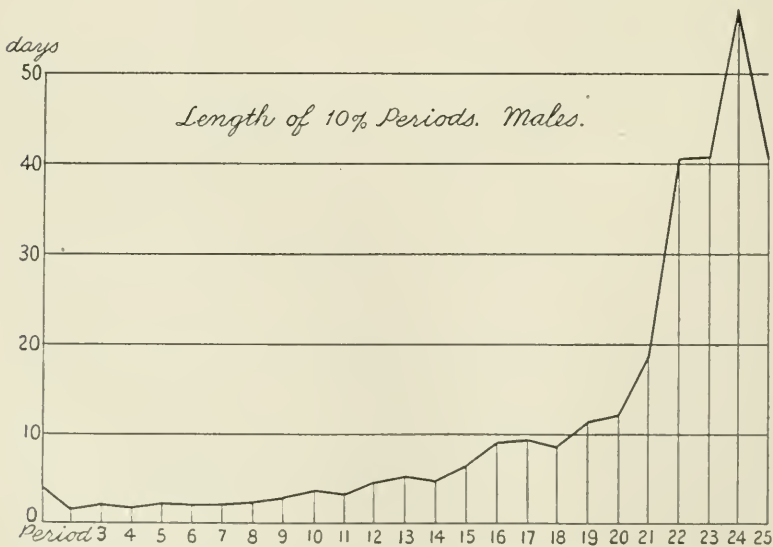


FIG. 23. CURVE SHOWING THE LENGTH OF TIME REQUIRED TO MAKE EACH SUCCESSIVE INCREASE OF 10 PER CENT. IN WEIGHT BY MALE GUINEA-PIGS.

in the rate of growth which will perhaps help to illustrate it; and in the next of our pictures we see this other form of representation before us. This vertical line represents the length of time which it takes a young male guinea-pig to add ten per cent. to its weight the first time. Here the third time—the fourth—the fifth—and you see as it is growing older and older it takes the animal longer and longer to add ten per cent. to its weight. Finally we get to the nineteenth addition, and we see that the period is very long indeed. How long that period is we can judge by the figures here upon the left, which represent the length of the days. From the base line to this one marked "ten" is a period of ten days, and you see from the time the guinea-pig has added to its weight ten per cent. for the nineteenth time it does it so slowly that it requires ten days and more; for the twenty-first time, nearly twenty; for the twenty-second time, nearly forty. Here where the number of observations becomes small, the curve grows very irregular. Thus we demonstrate that as the animal grows older it takes longer and longer to add ten per cent. to its weight. In the other sex, as the next slide shows, the same phenomena can be clearly demonstrated; here are the periods as before, lengthening out, as you see, at first; then becoming very long indeed. In the following slide I have another

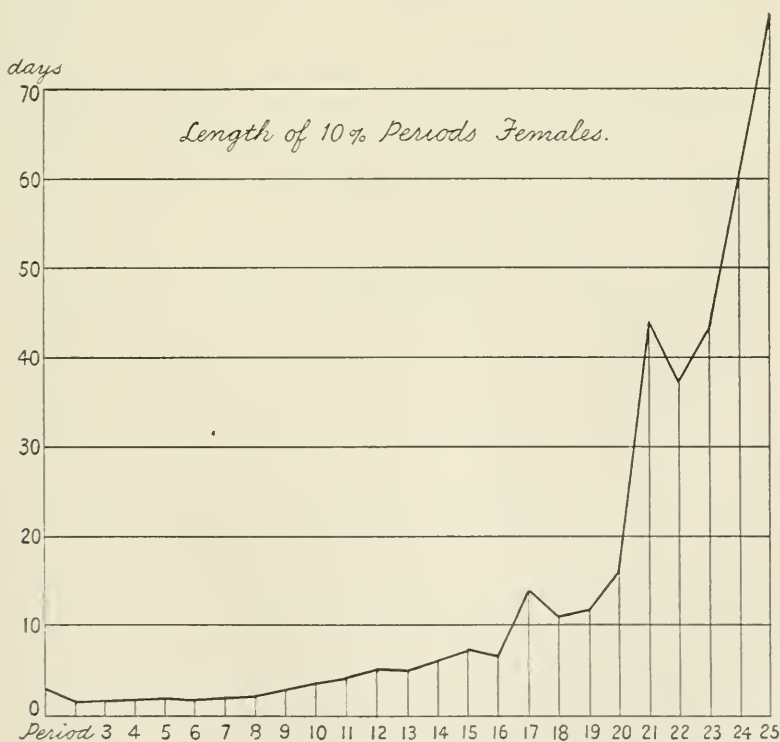


FIG. 24. CURVE SHOWING THE LENGTH OF TIME REQUIRED TO MAKE EACH SUCCESSIVE INCREASE OF 10 PER CENT. IN WEIGHT BY FEMALE GUINEA-PIGS.

form of representation of this same phenomenon as it occurs in the human subject. Here is a diagram of growth, which represents, as accurately as I could determine it, the curve complete for man from the date of birth up to the age of forty years. It has been calculated by a simple mathematical process where these ten-per-cent. increments fall, and from each point in this curve where there has been such an increment, a vertical line has been drawn, as you see here. These lines are very close together at the start. One ten per cent. after another follows in a short interval of time, but gradually the time, as indicated by the space between two of these vertical lines, increases, and when the individual is three years old, you can see there has been a very great

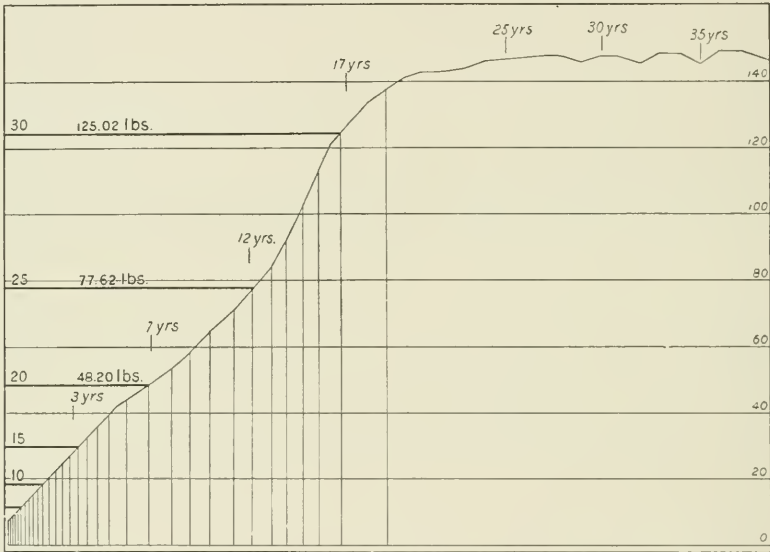


FIG. 25. CURVE SHOWING THE GROWTH OF MAN FROM BIRTH TO MATURITY, with vertical lines added to mark the duration of the periods, for each 10 per cent. addition to the weight.

lengthening out of the period which is necessary for it to add ten per cent. to its weight. Then it comes at the age of twelve to a period of slightly more rapid growth, a fluctuation which is characteristic of man, but does not appear in the majority of animals. After that comes very rapidly the enormous lengthening of the period; and I have not added the last ten per cent. because the curve here at the top, you see, is not very regular, and it could not be calculated with certainty. Our diagram is merely another form of graphic representation of the fact that the older we are the longer it takes us to grow a definite proportional amount.

The next slide carries us into another part of our study, away from the mammals which we have thus far considered, into the class of birds. The growth of chickens is represented here. Now a chicken is born in a less matured state than a guinea-pig, and has a good deal

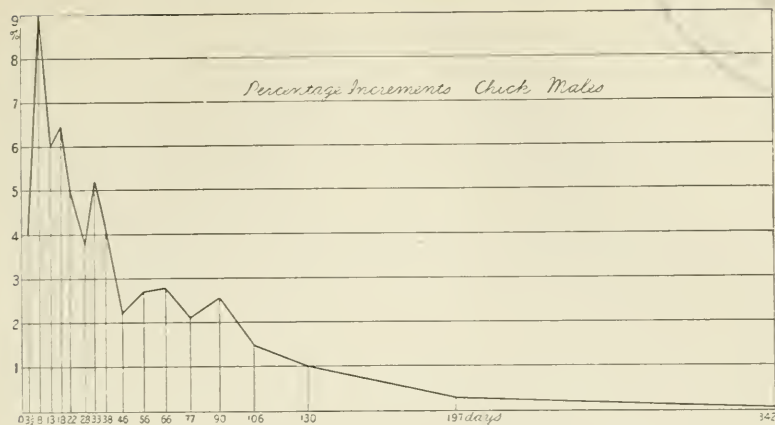


FIG. 26. CURVE SHOWING THE DAILY PERCENTAGE INCREMENTS IN WEIGHT BY MALE CHICKENS.

higher efficiency of growth at first. In a chicken, as in a guinea-pig, birth is a disturbing factor, and growth immediately after the hatching of the chicken is a little impeded, but the chick quickly recovers and, as we see, the first time when the rate can be distinctly measured we get a nine-per-cent. addition to the weight in a single day. In a chicken as in the guinea-pig, the rate gradually diminishes. The change from the rapid decline at first to the later slower decline is more gradual; the curve is more distinctly marked in the chicken as a round curve. There is not in the bird so marked a separation of the preliminary rapid decline and the later slower decline as we find in the guinea-pig. The curve again is very irregular because I had only a very limited number of observations upon the weight of chicks. The other sex, as the next slide will show, presents similar phenomena, though the female chickens do not grow quite as fast as their brothers. Here we notice an increase

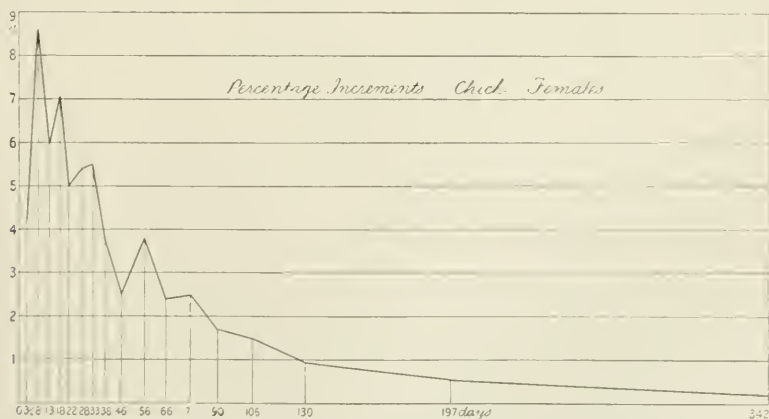


FIG. 27. CURVE SHOWING THE DAILY PERCENTAGE INCREMENTS IN WEIGHT BY FEMALE CHICKENS.

of almost, but not quite nine per cent., rapidly falling down so that after the chick is two months old it never adds as much as three per cent. to its weight. It loses in the first two months from a capacity to add nine per cent., down to a capacity of adding less than three. It loses in two months two thirds of its total power of growth, for from nine to zero is divisible into two parts, of which the first, from nine down to three, would be two thirds, and the second, from three to zero, would be one third. Here then we learn that two thirds of the decline which occurs in the life of a chick takes place in two months, and for the rest of the life of the bird there is a decline of one third. That, you must acknowledge, is an extraordinary and most impressive difference. If it be true that the more rapid growth depends upon the youth of the individual,—its small distance in time from its procreation, then we may perhaps, by turning to other animals which are born in a more immature state, get some further insight into these changes; and that I have attempted to do by my observations upon the development of rabbits. Rabbits, as you know, are born in an exceedingly immature state. They are blind, they are naked, they are almost incapable of definite movements, quite incapable of locomotion, and are hardly more than little imperfect creatures lying in the nest and dependent utterly upon the care of the mother, quite unable to do anything for themselves except take the milk which is their nourishment. They are indeed animals born in a much less advanced stage than are the guinea-pigs. Upon the screen we see this interesting result demonstrated to us, that a male rabbit, the fourth day after its birth, is able to add over seventeen per cent. to its weight in one day. From that the curve drops down, as you see, with amazing rapidity, so that here at an age of twenty-three days the rabbit is no longer able to add nearly eighteen per cent. daily, but only a little over six. At the end of two months from its birth, the growth power of the rabbit has dropped to less than two per cent., and at two months and a half it has dropped to one. The drop in two and a half months has been from nearly eighteen per cent. down to one per cent., and the rest of the loss of one per cent. is extended over the remaining growing period of the rabbit. Could we have a more definite and certain demonstration of the fact that the decline is most rapid in the young, most slow in the old? It is not in this case any more than in the others the one sex that demonstrates this fact, for in the female we find exactly the same phenomena, as the next slide will show. The irregularities are not significant. The strange dip at thirty-eight days, for instance, corresponds to an illness of some of the rabbits which were measured, but they rapidly recovered from it and grew up to be fine, nice rabbits. If instead of measuring half a dozen rabbits, we had measured two hundred or five hundred, these irregularities would certainly have disappeared. The females in the case of the rabbits, as in the case of the guinea-pigs, are not able

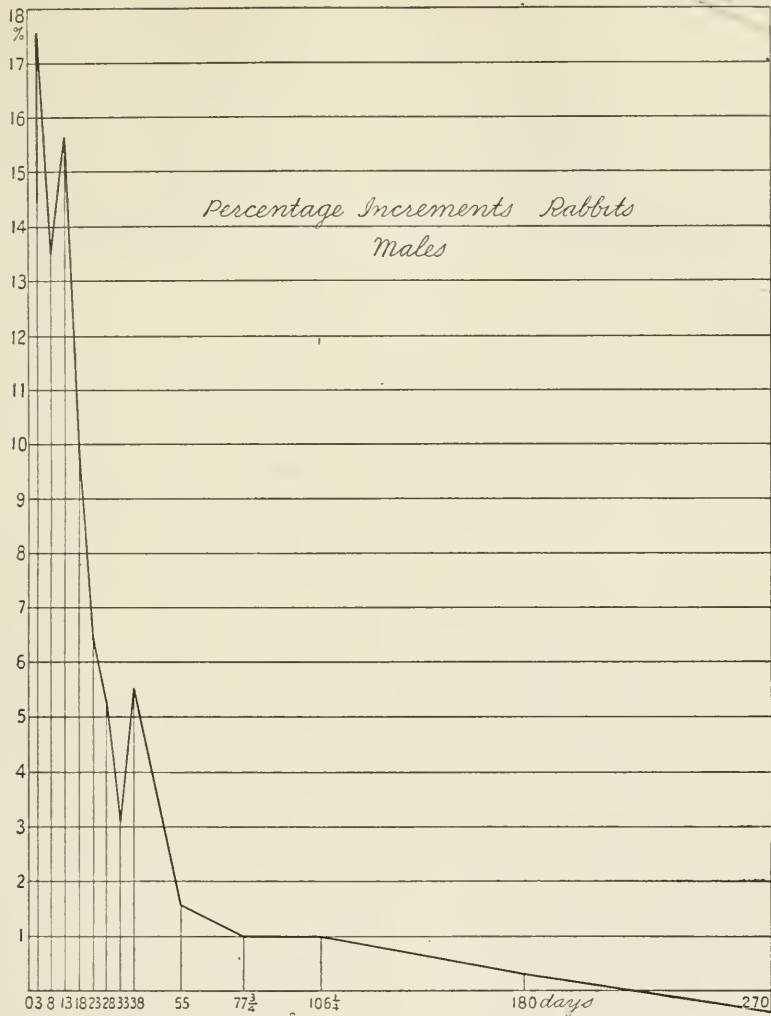


FIG. 28. CURVE SHOWING THE DAILY PERCENTAGE INCREMENTS IN WEIGHT BY MALE RABBITS.

to grow quite so fast at first. We see here sixteen instead of over seventeen per cent. as the initial value, but the general character of the drop is the same, enormously rapid at first and very slow afterwards. All of our cases, then, show the same fundamental phenomena appearing with different values.

Now in regard to man, we do not possess any such adequate series of statistics of growth as is desirable. We have many records of the weight of babies, by which I mean children from the date of birth up to one year of age. We have also very numerous records of school children, which will extend perhaps from five and one half up to say seventeen, eighteen or even nineteen years. There are records of boys

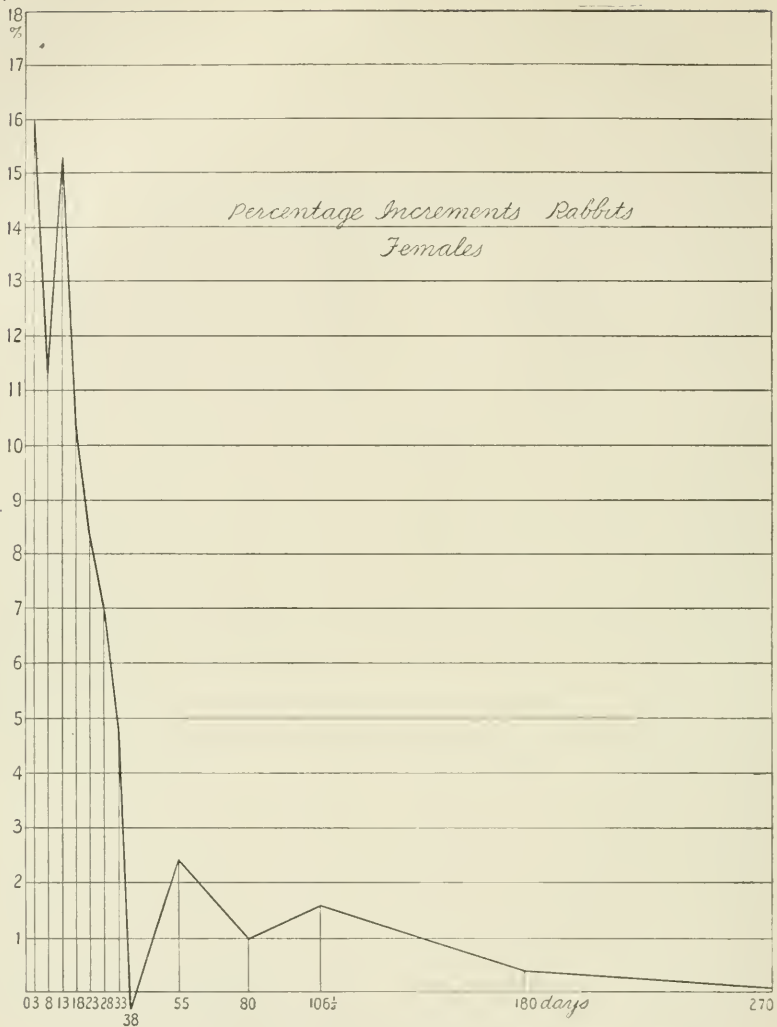


FIG. 29. CURVE SHOWING THE DAILY PERCENTAGE INCREMENTS IN WEIGHT BY FEMALE RABBITS.

at universities, and a still more limited number of weighings of girls at colleges. But all these statistics piled together do not give us one comprehensive set of data including all ages. This is very much to be regretted, and it would be an important addition to our scientific knowledge could statistics of the growth of man be gathered with due precautions. It would fill one of the gaps in our knowledge which is lamentable. We have, however, some rough, imperfect data which for our present purposes it seems to me are adequate, and the results of the study of these will be shown by the next series of pictures.

But let us pause for a moment to consider this singular table. It shows in this column the number of days which it takes for each species

TABLE¹

Species	Days Needed to Double Weight	100 Parts Mother's Milk Contain			
		Proteid	Ash	Lime	Phosphoric Acid
Man	180	1.6	0.2	0.0328	0.0473
Horse	60	2.0	0.4	0.124	0.131
Cow	47	3.5	0.7	0.160	0.197
Goat	19	4.3	0.8	0.210	0.322
Pig	18	5.9	—	—	—
Sheep	10	6.5	0.9	0.272	0.412
Cat	9½	7.0	1.0	—	—
Dog	8	7.3	1.3	0.453	0.493
Rabbit	7	10.4	2.4	0.8914	0.9967

of animal indicated at the left to double its weight after birth. A man requires 180 days to double his weight; a horse, 60; a cow, 47; a goat, 19; a pig, 18; a sheep, 10; a cat, 9½; a dog, 8; a rabbit, 6 (or possibly 7 days). Now here are analyses of the milk. The main point of interest is to be found in the figures in this column, which represent the amount of albuminoid, or proteid material contained in the milk. You will observe that for man the proportion is lowest, 1.6 per hundred parts; the horse has a little more—2; cattle—3.5; and so the values run. In other words, it is obvious that the less the proteid in the milk, the longer does the species require to double its weight. This looks at first sight as if there were a relation between the composition of the milk and the period of growth of the animal; but you know very well that if you take the milk of a cow, which is very much richer in proteid material, and feed it to a baby, a human baby, that baby does not grow at the same rate as the young cow, but grows at the human rate. It is obvious, therefore, that it is somewhat more complicated than a mere question of food supply. We have in fact one of the beautiful illustrations of the teleological mechanism of the body. These various species have their characteristic rates of growth, and by an exquisite adaptation, the composition of the mother's milk has become such that it supplies the young of the species each with the proper quantum of proteid material which is needed for the rate of growth that the young offspring is capable of. It is a beautiful adjustment, but there is not a causal relation between proteid matter and this rate of growth. It is an example of correlation, not of causation.

We pass now to the next of our slides, which carries us over into the study of our own species. It is not possible at the present time to represent in any form of curve which I have seen the daily percentages of increment for man covering the whole period of growth. In order to get the results together, I have confined myself here to the representation of the yearly percentages. Now from the age of zero to the age of one year, you see according to this table a child is able to increase its weight 200 per cent. But from the beginning of the first to

¹ After Abderhalden, *Zeitschrift für Physiologische Chemie*, Band XXVI., p. 497.

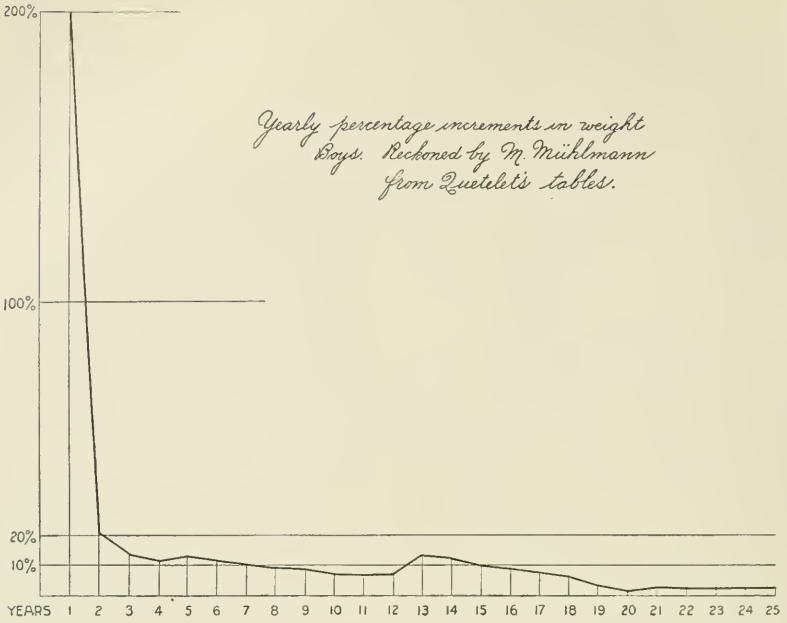


FIG. 30.

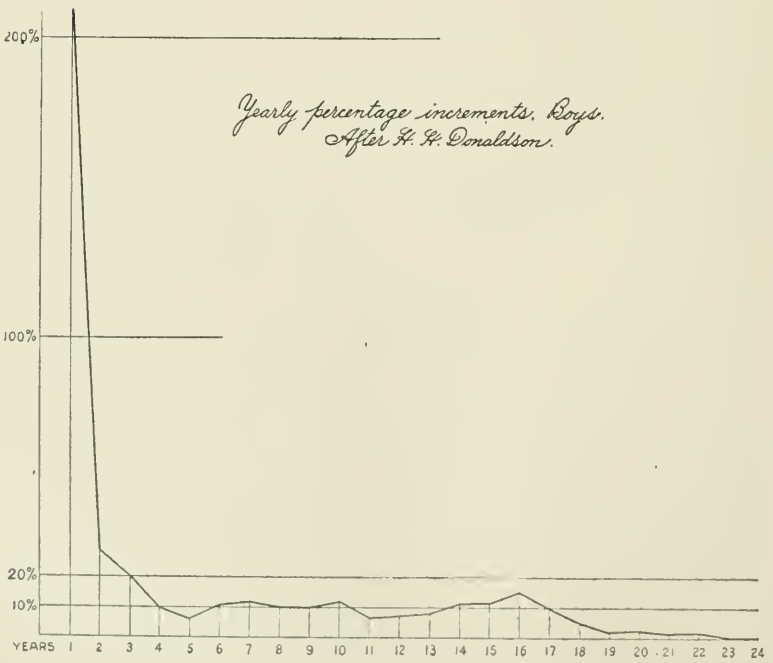


FIG. 31.

the end of the second year, only 20 per cent., and thereafter it fluctuates in the neighborhood of 10 per cent. a year until the age of 13. At 14 or 15 there is a fluctuation, an increase, and then the decline goes on again and slowly we see the growth power fading out. Authors are not agreed as to the exact statistical value, and so I will ask to have thrown upon the screen another curve, also representing the percentage increase of boys, and based chiefly upon English tables. For these data I am indebted to my friend Professor Donaldson, of the Wistar Institute in Philadelphia. He finds in these records an increment of a little more than 200 in the first year, but the drop comes during the second year and is startling in its enormous extent and is contrasted with the later less decline. The phenomena may well arouse our attention and convince us that we are approaching a most important scientific question, the question of why the drop comes in this way. In the case of girls, as the next of our slides will show, we can prove the same phenomena with slightly different values. Girls, like the females of other species, grow a little less forcibly, so to speak, than boys. They do not quite

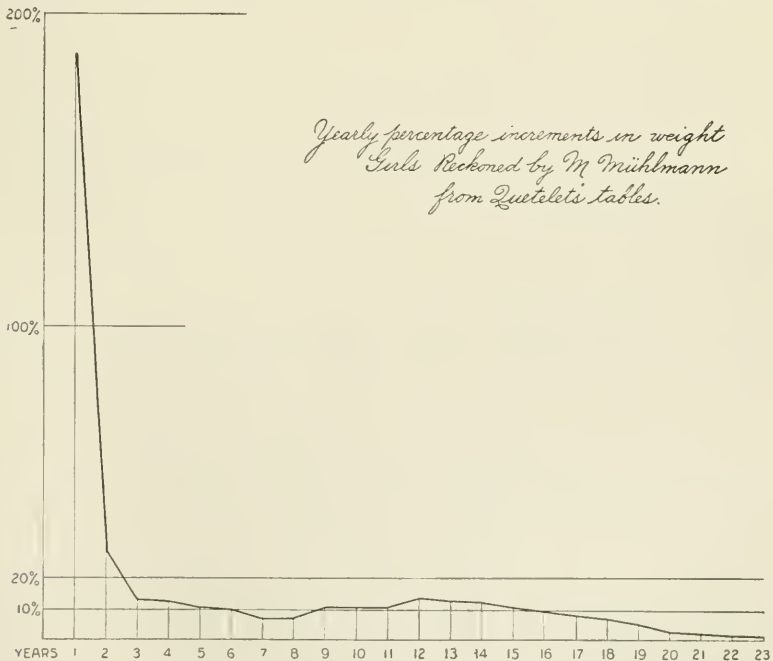


FIG. 32.

attain a 200 per cent. value for the first year, but they too drop in a similar manner to the boys to about 30 per cent., and away down towards 10 per cent. in the third year. Then comes the long slow gradual decline up to the period of twenty-three. Professor Donaldson, as our next slide will demonstrate to us, has prepared curves from the English figures for girls also. They come up nearer to the 200 per

cent. than in Mühlmann's table, but drop well below 30 per cent. in the second year, and down to 20 per cent. in the fourth. Then occurs the slight increase of growth in the period of twelve, thirteen, fourteen years, and next the final stage of decline. In the four cases the human rate curve is similar. The great fall takes place at the beginning, the slow fall towards the end. Professor Thoma has thought he could get somewhat more accurate results by putting boys



FIG. 33.

and girls together, and he has made a calculation, as shown now upon the screen, of a curve in which the two sexes are combined. His figures again differ somewhat from those we have considered, but you meet in this curve also the same general phenomena. There is an enormous percentage of growth during the first year; an enormous drop during the second; then the slow decline; the moderate fluctuation upward; and then the last slow disappearance of growth. In every instance, therefore, we have an absolute demonstration, it seems to me, of the strange phenomenon. Paradoxical it will sound, whenever it is first stated to any one, that the period of youth is the period of most rapid decline; that the period of old age is that in which decline is slowest. We shall learn in the next lecture that this double phenomenon furnishes us a clue to further investigations, and leads to certain new inquiries, which enable us to gain some further insight into the essential nature of the phenomena of age.

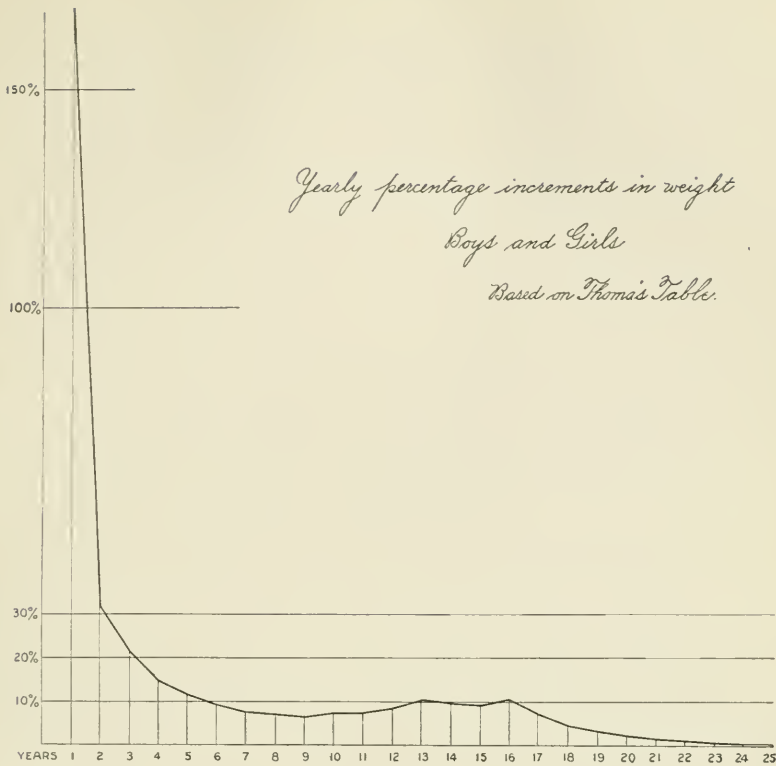


FIG. 31.

This completes the series of curves which I had prepared to present to you to show the rate of growth in animals from their birth only, but of course there has been also a growth of the animals which preceded their birth, and that now must briefly be considered.

The mere inspection of developing embryos of known ages gives us some idea of the rate of growth. With the aid of the lantern I will ask you to look with me at some pictures of the developing chick and developing rabbit. Let us begin with the chick.²

² During the lectures a series of lantern slides were projected upon the screen, made from photographs of mounted specimens of chicken embryos, which showed very clearly the progress of development in the chick during the very early stages. The first figure illustrated a chick of 18 hours' incubation. The embryo had been skimmed off from the surface of the egg, hardened, colored artificially and mounted in the manner of the ordinary microscopical preparation in Canada balsam. At this age the naked eye can just distinguish a line, which indicates the position of the axis of the embryo. The unaided eye can recognize nothing more. In the second picture the head and neck of the embryo were easily distinguishable, and a few of the earliest primitive segments. The third slide showed a stage of a day and a half. The spinal cord and brain were distinctly differentiated, and numerous so-called "blood islands" scattered about.

We have first an embryo of twenty hours of incubation; following it one of one day. You can observe just a little line of structure indicated and showing where the longitudinal axis is to be situated. By the second day the chick has distinctly a head and a little heart, and those who are expert can differentiate with a microscope the axis of the body, the beginning of the formation of the intestine and of the muscles. At the end of the first day there was little more than a mere gathering of cells, but during the twenty-four hours of the second day the gathering has changed from a mere streak upon the surface of the yolk to a well-formed individual, with recognizable parts and several times the volume it had when one day old. The next figure illustrates the alteration which occurs during, approximately, the third day. It is obvious that the embryo has again made an enormous increase in volume. The eye has developed, the heart has become large, the tail is projecting, the dorsal curve of the future neck is distinguishable. We pass next to the fourth day. Is it not a strange looking beast, with its wing here and leg there, a little tail at this point; an enormous eye, almost monstrous in proportion; and, finally, here a bit of the brain. After five days we have a chick the brain of which is swelling, causing the head to be of so queer a shape that, with the eye, which seems out of all proportion to the rest of the body, it imparts an uncanny look to the embryo. The wing is shaping itself somewhat, and the ends of the leg, we can see, will, by expansion, form a foot. Finally, the chick after seven and after eight days is figured. In the short interval of only six days the chick grows from the size represented by Fig. 2 to that shown in the last figure upon the plate. It is an enormous increase. Suppose a chick after it was born were to grow at such a rate as that! The eight-day embryo is thirty or forty times as big as it was eight days before. It would seem marvelous to us if a chick after it was hatched should become in eight days thirty times as large and heavy as when it first came out from the egg. It is perhaps advisable to let you follow the growth of the chick a little farther, and accordingly I present another picture which shows an embryo of about ten days. The little marks upon the surface of these embryos indicate the commencing formation of the feathers. A comparison of the series of figures proves that the development is taking place with marvelous speed. We need only to look at these stages, comparing them with one another, to realize that the progress of the embryo in size and development occurs with a rapidity which is never to be found in later stages.

The history of embryonic rabbits declares with equal emphasis that the earliest development is extremely rapid. I wish now to show you

The final slide of the series showed a chick of three and one half days. It has not seemed necessary to reproduce these figures with the present text, as they merely duplicate, on a larger scale and with more detail, the pictures which have been included.

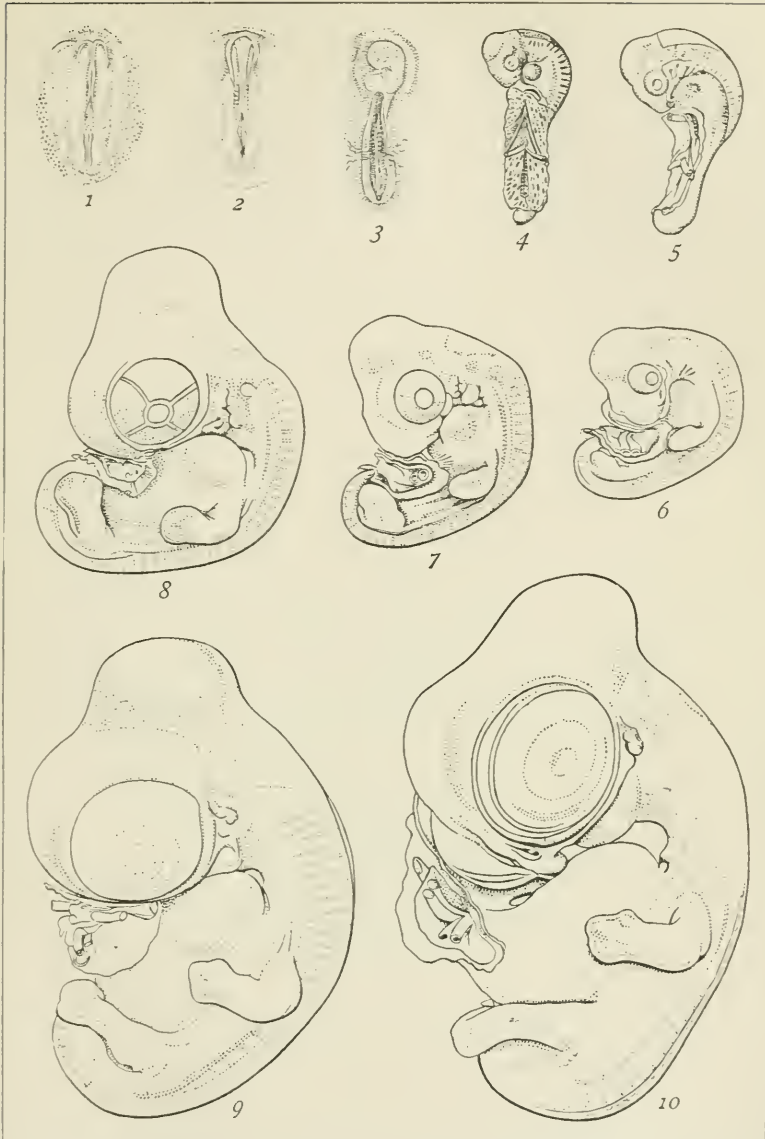
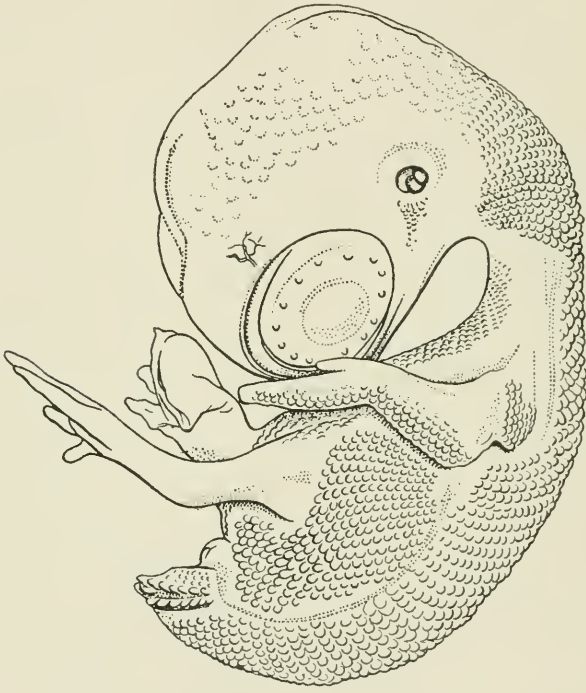


FIG. 35. TEN STAGES OF THE DEVELOPING CHICK, after Franz Keibel. All the figures are magnified four diameters. In No. 1 only the parts indicated in the vertical axis of the figure correspond to embryonic structures proper.

No. 1.	Incubated 20 hrs.	No. 6.	Incubated 3 days, 16 hrs.
No. 2.	" 24 hrs.	No. 7.	" 4 days, 8 hrs.
No. 3.	" 2 days.	No. 8.	" 5 days, 1 hr.
No. 4.	" 2 days, 19 hrs.	No. 9.	" 7 days, 1 hrs.
No. 5.	" 2 days, 22 hrs.	No. 10.	" 8 days, 1 hr.

a series of pictures to illustrate in the same manner the progressive development of the rabbit. Numbers one to five of the figures upon the screen represent what is known as the germinal area, in the center

of which the actual embryo is gradually formed. In No. 1 merely the axis is indicated, in front of and alongside of which the parts of the embryo are to arise, as is suggested by Nos. 2, 3, 4, 5. These stages cover the seventh and eighth days. Nos. 6 to 14 figure actual embryos, No. 6 of nine and a half, No. 14 of fifteen days. No. 6 is singularly twisted into a spiral form, the reason for which is still undiscovered. No. 9 shows the condition at eleven days—notice the limbs, a leg in front and a leg behind, each only a small mound as yet upon the sur-



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FIG. 36. A CHICK REMOVED FROM AN EGG, WHICH HAD BEEN INCUBATED 10 DAYS AND 2 HOURS. Magnified four diameters. After Keibel.

face of the body; the distinct eye, the protuberance caused by the heart. Nos. 11 and 12 show the embryonic shape at twelve and a half and at thirteen days—there has been a great increase of size with accompanying modifications of form. The next pair, Nos. 13 and 14, present us embryos of fourteen and fifteen days, respectively, and you see that the growth is very marked indeed, and the change of form obvious; the creature is now changing from the embryonic type into something resembling a rabbit. Other pictures could readily be added, but, though two weeks must still elapse before the animal will be ready to enter the world, it is not necessary for my present purpose to include this period in our survey. We need only contemplate, it seems to me, the series of drawings in Fig. 37 to realize that the early embryonic growth

of the rabbit, like the embryonic growth of the chick, proceeds with a speed which is never paralleled by the growth during later stages.

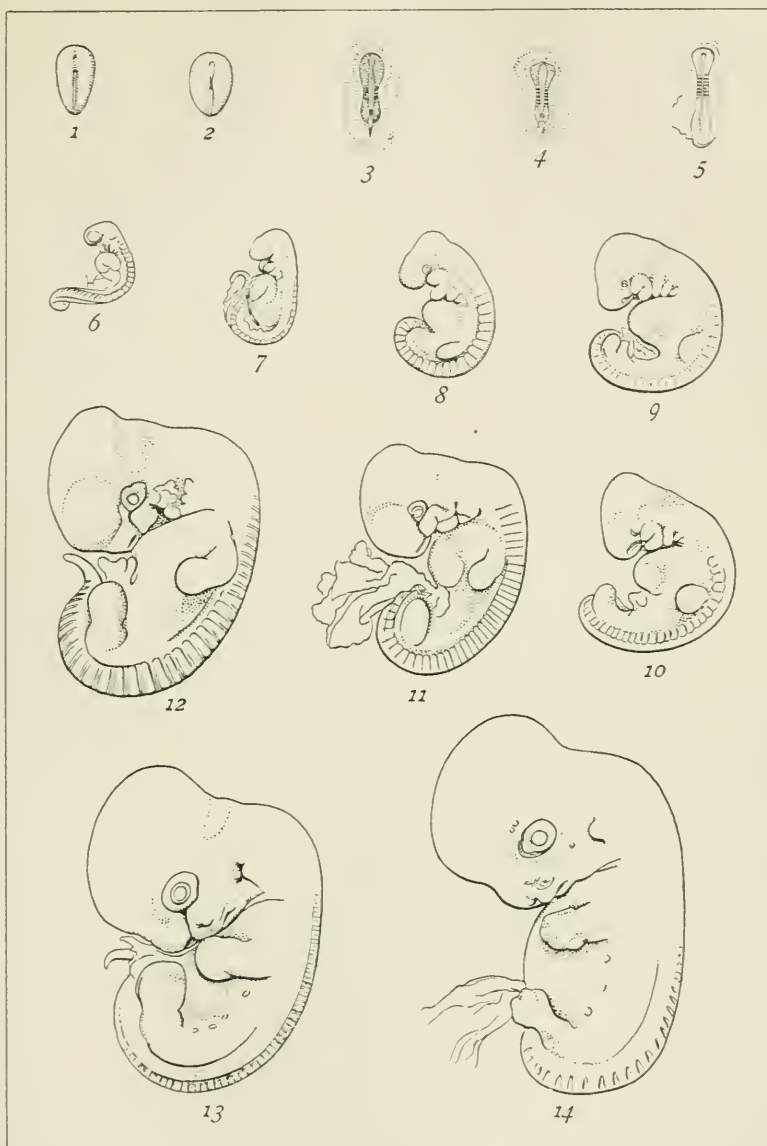


FIG. 37. FOURTEEN STAGES OF THE DEVELOPING RABBIT, after Minot's and Taylor's "Normal Plates." All the figures are magnified four diameters. Nos. 2 to 5 are irregular as to age, but show successive stages of development. The early development is extremely variable and the observations do not yet suffice to determine the average typical condition for each day under nine.

No. 1. Embryo of $7\frac{1}{2}$ days.
 No. 2. " $8\frac{1}{4}$ "
 No. 3. " $8\frac{1}{4}$ "
 No. 4. " 8 "
 No. 5. " $8\frac{1}{2}$ "
 No. 6. " $9\frac{1}{2}$ "
 No. 7. " 10 "

No. 8. Embryo of $10\frac{1}{2}$ days.
 No. 9. " 11 "
 No. 10. " $11\frac{1}{2}$ "
 No. 11. " $12\frac{1}{2}$ "
 No. 12. " 13 "
 No. 13. " 14 "
 No. 14. " 15 "

Now I had a considerable number of rabbit embryos preserved in alcohol, and though it was not very accurate to weigh them as alcoholic specimens, in order to determine their true weight, yet I resolved to do so as it was the best means at my disposal at the time. The result of that weighing was very interesting to me, because it showed that in the period of nine to fifteen days the rabbit had, on an average, added 70½ per cent. to their weight daily; but in the period of from fifteen to twenty days, the addition is very much less than this, only 212 per cent. But these rabbits at ten days have already had a considerable period of development behind them, and as we have discovered that the younger the animal the more rapid its growth, we are safe, it seems to me—since we have learned that from the tenth to the fifteenth day there is a daily increase of over 700 per cent.—in assuming that in yet younger rabbits an increase of a thousand per cent. per day actually occurs. That is not so extraordinary an assumption, for bacteria are known to divide every half hour, and if the little bacterium divides and grows up to full size in half an hour, and then divides again, it means that within a half hour one bacterium has become two, and has increased, obviously, 100 per cent.; and if those two again divide as before, we should have four bacteria at the end of an hour—an increase of 400 per cent., and at the end of another half hour, of 800 per cent., and so on ever in geometrical progression. We learn, then, that bacteria may in a few hours add 1,000 per cent. to their original weight, and it is not by any means an exorbitant demand upon our credulity to accept the conclusion that in their early stages, rabbits and other mammals and birds are capable of growing at least 1,000 per cent. a day. If this be true, and it doubtless is true, we can adopt it as a convenient basis for comparison. As we learned from the rate curves, which were projected upon the screen earlier during the hour, the male rabbit gains in one day immediately after birth nearly eighteen per cent.—seventeen and four tenths per cent.—and the female rabbit gains nearly seventeen per cent. Now we can estimate the loss very simply by deducting this rate, which is the capacity of the animal to grow persisting at birth, from its original capacity, which we assume to have been 1,000 per cent. per day. And if we do that the result is obvious. Over 98 per cent. of the original growth power of the rabbit or of the chick has been lost at the time of birth or hatching, respectively, and the same thing is equally true of man. We start out at birth certainly with less than two per cent. of the original growth power with which we were endowed. Over 98 per cent. of the loss is accomplished before birth—less than two per cent. after birth. That, I think is a rather unexpected conclusion, certainly not one which, until I began to study the subject more carefully, I in the least expected; and even now when I have become more familiar with it, it still fills me with astonishment, it is so different from the conception of the process of development as we commonly hold it, from our conclusions based on our acquaintance

with the growth and progress of the individuals about us. We overlook the fact that the progress which each individual makes is the result of accumulation. It is as if money was put into the savings-bank; it grows and becomes larger, but the rate of interest does not alter. So too with us; we see there is an accumulation of this wealth of organization which gives us our mature power. But as that accumulation goes on, our body seems to become, as it were, tired. We may compare it to a man building a wall. He begins at first with great energy, full of vigor; the wall goes up rapidly; and as the labor continues fatigue comes into play. Moreover, the wall grows higher, and it takes more effort and time to carry the material up to the top of the wall, and to continue to raise its height, and so, as the wall grows higher and higher, it grows more slowly and ever more slowly, because the obstacles to be overcome have increased with the very height of the wall itself. So it seems with the increase of the organism; with the increase of our development, the obstacles to our growth increase. How that is I shall hope to explain to you a little more clearly in the next lecture.

We have one more slide, which I would like to show you. It indicates the rate of growth in man before birth as far as it can be indicated without better knowledge. The time intervals in the diagram correspond to the so-called lunar months—the ten lunar months of prenatal

life. Of our early development we know very little so far as statistics are concerned, but from the third month onward we have some records. It is found that from the third to the fourth month the increase is 600 per cent. Just contrast that with 200 per cent. added in one year after birth; 600 per cent. in one month against 200 per cent. in one year. From the fourth to the fifth month it is scarcely over 200 per cent. It then becomes only a little more than 100. In the seventh month, less than 100; and finally in the ninth and tenth months, it

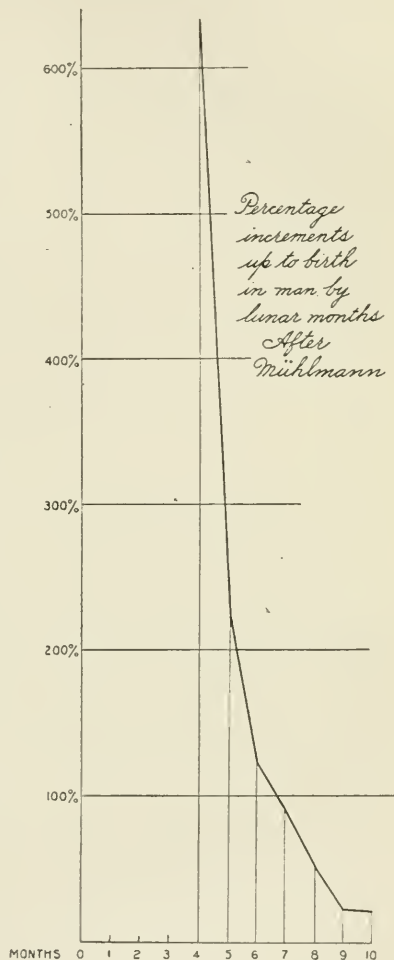


FIG. 38.

becomes very small indeed, less than 20, so that during the prenatal life of man, as we have seen in the prenatal life of the rabbit and of the chick, the decline in the power of growth is going on steadily all the time.

I shall use the few remaining moments to report to you yet another bit of evidence of the originally enormous power of growth. It has been estimated that the germ of the mammal, with which the development commences, has a weight of 0.6 milligram; another estimate which I have found is of 0.3 milligram.³ Perhaps I can give you some idea of what this value means by telling you that if the weight of the original germ of a mammal is assumed to be 0.6 milligram, we could, according to the laws of the United States, send 50,000 such germs by letter postage for two cents. It would take 50,000 germs to make the weight of one letter. That perhaps will give you some impression of the extreme minuteness of the primitive germ. In the human species at the end of even a single month it is no longer merely a germ, but a young human being, very immature, of course, in its development, but already very much larger. I doubt—even after all that I have said this evening about the startling figures of growth for the earlier stages,—I doubt if you are prepared for the fact that the growth of the germ up to the end of the first month represents an increase of over a million per cent. How much over a million per cent. we can not calculate accurately, because we do not know accurately the weight of the original germ, but an increase of a million per cent. is not above the true value. Contrast that with anything which occurs in the later periods. What a vast change has happened! What an immense loss has taken place! The rate of this loss is evidently diminishing. The loss occurs with great rapidity in the young—less rapidity the older we become. I attempted to convince you in the first and second lectures that that which we called the condition of old age, is merely the culmination of changes which have been going on from the first stage of the germ up to the adult, the old man or woman. All through the life these changes continue. The result is senility. But if, as the phenomena of growth indicate to us so clearly, it be true that the decline is most rapid at first, then we must expect from the study of the very young stages to find a more favorable occasion for analysis of the factors which bring about the loss in the power of growth and change as the final result of which we encounter the senile organism. Not from the study of the old, therefore, but from the study of the very young, of the young embryo, and of the germ, are we to expect insight into the complicated questions which we have begun to consider together. I shall hope in the next lecture to prove to you that the supposition which has guided my own observations is correct, and to be able to show you that we do actually, from the study of the developing embryo, glean some revelations of the cause of old age.

³ These estimates refer to the placental mammals only.

A SCIENTIFIC COMEDY OF ERRORS

BY PROFESSOR T. D. A. COCKERELL AND PROFESSOR F. B. R. HELLEMS
UNIVERSITY OF COLORADO

THE scientific man of any period, if he will examine the work of his predecessors, may be comforted or discouraged, according to his point of view. It is in the highest degree encouraging to note the steady and rapid progress of science during the last two hundred years and more. It is flattering to the vanity of us moderns to realize that we stand on the very apex of the pyramid of knowledge which the human race has erected at the cost of so much toil, and can look down with indulgent contempt on the comparative ignorance of earlier generations. How stupid they were! How little they knew!—but we—well, there really never has been anything so superior. There is, however, an ancient story about a monkey which climbed a pole and for every three feet he climbed he slipped down two. Was the animal, after all, certainly a monkey? Is there no similarity between his progress and that of the human race? If the science of the past reads to us to-day like a comedy of errors, is it perfectly certain that our productions will not so appear to that hateful body of supercilious critics, our posterity? On second thought, there may be in the history of human learning as much cause for modesty as for exultation. As a tangible case in point we present a summary of the early history of the cochineal and allied dye-producing insects, and more particularly of a forgotten pamphlet by one Frederic Friedel, whereby he earned the degree of doctor of philosophy at the University of Leipzig, in 1701. For his time, Friedel was a man of unusual wisdom, filled with the true spirit of science, so much so that he was not afraid to tilt against the greatest of biological authorities then living, and, in so doing, came out with a flying pennant. Yet, in the light of modern knowledge, it appears that he corrected the blunders of Leeuwenhoek only to make somewhat lesser ones of his own; not, however, through lack of care or lack of sense, but from the unavoidable imperfection of his knowledge.

From very early times, it was customary to utilize the coloring matter obtainable from certain small round objects to be found on various species of oaks in the region of the Mediterranean. Dioscorides and other authors report their occurrence in Galatia, Armenia, Sicilia, Spain, Portugal and Sardinia: in later times they have been known in the south of France, Crete and Syria; while the north of Africa has furnished a less valuable kind. To Theophrastus they were known

Q. D. B. C. F.

Inclyto Philosophorum Lipsiensium
Ordine consentiente,

DISSERTATIONEM PHYSICAM
DE

COCHINILLA

H. L. Q. C.

Ad d. 1^o Mart. Anno 1701.

Placido Eruditorum Examine publice subjiacet

P R Æ S E S

M. CHRISTOPH. FRIDERICUS

Richter / Lipsiensis,

RESPONDENTE

FRIDERICO Friedel / Scaudiza-Ciz. Misn.

Med. Cult.

L I P S I Æ,

Excudebat **CHRISTOPH. FLEISCHERUS.**

as the *κόκκος φοινικός*, while in later times the name *Kermès*, from the Arabic, came into general use.

For many centuries the nature of the Kermes remained uncertain. To all appearances it was a berry, and the opinion that it was of purely vegetable origin prevailed. However, it appears that Quinquaran de Beaujeu, as early as 1551, published a book on the productions of Provence, entitled *De laudibus Gallo-Provinciæ*, in which he clearly indicated that the Kermes was an insect, and described its transformations. The supposed berries, says he, are the mothers, who presently have families of innumerable very minute worms. These latter locate upon the twigs at various points, increase in size, and at length look no longer like animals, but peas.

Planchon, to whom we are indebted for the reference to Quinquaran, goes on to remark that it is curious that after these observations had been published, many intelligent writers showed hopeless confusion upon the subject. In particular, it had been observed that from the Kermes sometimes issued small four-winged insects not unlike those coming from the oak-apples or galls. Hence it was concluded that the Kermes must be a sort of plant gall, wholly made up of

vegetable tissue, but nourishing an insect. We know now, of course, that the four-winged insects were merely parasites of the Kermes, which lived as minute maggots within its body, destroying it and finally issuing as adult flies.

With the discovery of Mexico, things took on a new turn. Francisco Hernandez and others reported that on the tuna, or prickly pear, of that country there grew a new sort of coccus, which was much to be preferred to the one found upon the oak, or to the scarlet grain found upon the roots of plants in Poland.

This new coccus, which came to be known as the cochinilla, or cochineal, was largely imported into Europe; and eventually the cacti were brought over, and grown in Algeria, Madeira, etc., so that the dye-material could be produced nearer the market. With the impetus thus given to the study of coccus—or, as we should now say, the Coccidæ—the question as to the true nature of the material pressed anew for settlement. According to the “Encyclopædia Britannica,” the idea that the cochineal was the seed or fruit of a plant was prevalent as late as 1725, but Martin Lister, in 1672, indicated its relation to the insects. In 1703, it is stated, Leeuwenhoek discovered its true nature by the aid of the microscope, “but not unnaturally supposed it to be allied to the ladybird.”

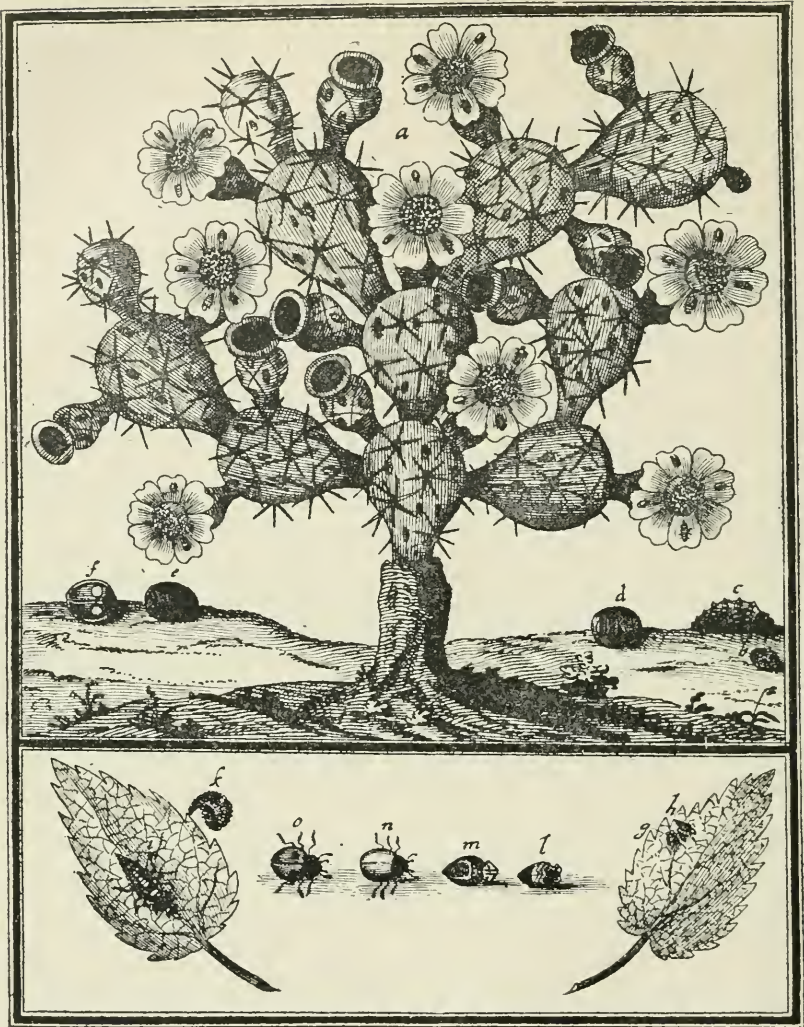
This statement of the case, however, is not quite exact. We have before us a little pamphlet published as early as March, 1701, the precise date, according to a penciled figure, being the fourteenth of that month. This work is a thesis for the degree of doctor of philosophy, presented to the University of Leipzig by Frederic Friedel, and is entitled *Dissertatio Physica de Cochinilla*. In it, the whole question of the nature of the cochineal is fully discussed, with copious references to previous authors and many original observations.

The work consists of six chapters; the first on the name of the cochineal; the second on its habitat and the plants infested, with some interesting information on the different kinds of cacti; the third on various opinions concerning the nature of the cochineal; the fourth giving the details of the author's views as to its nature; the fifth on its culture and the methods of collecting it; and the last on its different varieties and its uses. The whole treatise is, of course, in Latin, but we give a free translation of the parts with which we are particularly concerned, abbreviating here and there.

After giving a general summary of the hitherto recorded observations and opinions, Dr. Friedel proceeds:

Therefore, this insect is a Coleopteron [beetle], so to speak sheath-winged, or in a word, belonging to the family of lesser scarabs, which we recognize by the almost round body, flat below and convex above, not less than by a reddish and golden color, sprinkled with some black spots.

He then proceeds to set forth the names for the ladybird in dif-



ferent languages, bringing out the fact that these creatures are dedicated to Our Lady, the Virgin Mary, or in other cases to God, for reasons not explained. In France they are called God's horses, *Chevaux de Dieu*, in England ladybirds or cowladies, and so forth.

To these familiar ladybirds,

such exact resemblance is borne by the little animals which produce the cochineal, that one egg could scarcely be more like another, if only you except the size, in which the American beetle is observed to surpass ours, and the color, which is not vividly red or scarlet or yellow in the foreign species, but dull and brownish, with the spots red, the latter larger than those on our beetles.

The modern entomologist begins to wonder what all this has to do with

the cochineal, which is by no means a beetle, though truly an insect, but the author proceeds:

Moreover, these statements that I have made about the form and appearance of this beetle, that they may not be accounted the mere offspring of my brain, can all be easily verified by actual examination; for dry specimens, complete, generally, however, with the head and feet torn off, are found mixed with the cochineal; or at least, as happens more commonly, elytra are brought out along with the cochineal grains. I myself have found several points concerning these little animals, complete or intact for the most part, which exactly agreed with those just described, so that all occasion for doubting the truthfulness of the facts has been removed.

With this description, aided by an excellent figure given in the one plate which ornaments the pamphlet, we are able without difficulty to explain the mystery. The American beetle is the *Chilocorus cacti*, a genuine ladybird, which does indeed live upon the tuna among the cochineal insects, *feeding upon them*. When the latter are gathered, the beetles are often carried with them, and Friedel, examining the dried grains, naturally found the specimens he describes. In 1701 not much was known about the classification of insects, and it never occurred to him that a creature like the cochineal, which we now know to have a sucking mouth, could not be related to a beetle.

Yet, aware that scoffers exist, the author is constrained to proceed:

Howbeit, if this evidence of mine should not find full credence, look you! here is Paulus Ammannius, who in his handbook to *Materia Medica* reports that he also found such a little animal intact; and if perhaps he is not sufficient authority either, take Leeuwenhoek and Tyson, of whom the former depicts little insects of this type, found by him likewise, and the latter even gives an engraving on copper of a cochineal scarab, and when you have compared the figures, you will agree that it is as closely similar as possible to mine. In the appended plate, I offer one of those that I happened to find, along with our nettle beetle [that is, the European ladybird, *Adalia bipunctata*], because the difference, as well as the resemblance between them, will thus better meet the eye. I willingly omit the references to other authors, such as Blanchard (*Schauplatz der Raupen*) and Dale (*Pharmacology*), for the two just mentioned, Leeuwenhoek and Tyson, are for me equivalent to all.

Friedel then proceeds to combat an opinion, which he attributes to Leeuwenhoek and an anonymous Spaniard mentioned in the *English Transactions* (of the Royal Society) No. 193, to the effect that the cochineal is a portion of the adult American ladybird—the *Chilocorus cacti*.

For it is disproved by ocular examination, that the lower belly of this beetle, if it shall have been stripped of its legs and head, and finally of its elytra and wings, as indicated by Leeuwenhoek, exactly resembles the cochineal. Rather, the form of these hinder parts of the insect differs as much as possible from the little body of the cochineal; seeing that in the first place, in size it generally very greatly surpasses the lower belly of the beetle, as I have found in more

than one case when I have removed from the intact beetles found among the cochineal the parts just mentioned; and in the second place, I have noticed this marked discrepancy, the abdomen of the beetle is never marked by more than six or at the most seven distinct rings, but the number of these in every grain of cochineal generally runs as high as 12, as can be seen with the naked eye, or more distinctly with the aid of the microscope, especially if the insect has been softened in water. Furthermore, a third difference will be noticed at the same time—you will certainly observe the anterior half of the cochineal to be furnished with some little swellings, beneath which lurk the feet of the insect which are going to appear, and which the engraver has tried to show in the cut. On the other hand, that the hinder parts of the beetles are always entirely devoid of these swellings an examination places beyond limits of doubt. Add to all these the fourth circumstance that the abdomen of the beetle does not produce any purple color, and for that reason could little serve the purpose for which this ware is imported from such distant shores. Although I subjected certain of these trunks of the lower belly to different treatments, I never was able to see even a tiny point of the desired color in them, while conversely, any tiny cochineal will discharge the color in sufficient abundance and at once. And finally, I have never been able to find in the belly of the beetle a single little grain or egg, although I sought most zealously; whereas such are found in great abundance in any cochineal which is broken up after having been sufficiently macerated.

What an excellent argument! It is proven beyond doubt that the cochineal is no part of the ladybird, notwithstanding the assertions of the most eminent authority then living. We have no fault to find with particulars given, except that the little prominences on the cochineal, where the legs were hereafter expected to appear, were in reality the bases of the minute legs of that insect.

Returning now to the constructive argument, the author gives his conclusion that the cochineal must be derived from the aforesaid beetles, and yet is not any part of them. The simple explanation is that the cochineal, when mature, transforms into a beetle, and in doing so utterly loses the power of staining, and hence is no longer to be termed a cochineal. Now this loss of color at maturity is paralleled by other phenomena already recorded. In the case of the dye-coccus of the oak, the *Kermes*, so long as the little berries are full of little worms or animals, they are rich in the colored juice. After a while, when the little worms [the larvæ of the *Kermes*, in reality] are called by the heat of the sun from their sacs [that is, the bodies of their mothers] they can be destroyed by the pressure of the hand, and forced into a mass which is appropriately termed vermilion. Otherwise, before the exclusion of the worms, the dried berries will equally preserve the desired color. It is just the same in the *coccus polonicus* [*Margarodes polonicus* of modern entomologists], which is said to cling to the roots of several herbs. These little bodies at a stated time turn into little winged insects, as is stated by several authors, including Martin Bernhard in his description of the Royal Garden of Varsovie. As soon as

these insects [probably males of the *Margarodes*] fly away, they are manifestly deprived of all color, and not only this, but the cortex which is left retains nothing of the precious coloration.

So, says Friedel, since in all these different sorts of coccus the red color disappears in the last stage, when the creature is transformed into a fly or some other little animal, it is easy to understand why the beetles produced from the cochineal show no red pigment. The point is important, because it is necessary that the cochineal should be collected in time, before its last transformation, and while it is still swollen with the juice.

The analogy is here not very convincing, since the *Kermes* does not turn into a single insect, but produces a multitude of "worms," as Friedel clearly states. It seemed sufficient to him, however, and he never got a glimpse of the true fact that the cochineal insects do indeed turn into the beetles, in the same manner that the lamb may be said, under suitable circumstances, to be transformed into the lion.

Assuming that the cochineal was the pupa of the beetle, it remained to fortify this conclusion by still other arguments. In the first place, Herrera and Laetus had given some slight account of the development of the cochineal, from actual observation. From this it might be gathered that there was at first a minute or mite-like insect, which developed into the cochineal-grain. This accords very well, so far as it goes, with what was to be expected according to the theory. "That grain is covered on the outside by a certain thin tunic, which contains shut up within it the little animal, which is soon to be transformed into a beetle"—this is, however, an inference of Friedel's, not of Herrera's.

"But," says Friedel, "for a more beautiful illustration of my hypothesis, I thought I might describe the transformation of the European ladybird, which is certainly sufficiently allied to the American to permit accurate deductions to be drawn from it." So he went first to the book on insects by John Goedart "that very illustrious painter of Middleton," a work which several years back Martin Lister had published in a new and revised edition. In this work, p. 274, it appeared that first from little blackish eggs deposited in a sort of circle on the leaves of the *Ribes* [currant or gooseberry], there sprang, "from the nurturing of the summer air," little animals, which immediately after hatching could scarcely move, until after an interval of several days they learned to creep a little, and finally to run about freely. These insects were subsequently observed to shed their skins, like serpents, as they increased in size, and this was done four distinct times, and last they obtained the final red skin, variegated with black spots. To these statements the author added that as often as these beetles stripped themselves of their skins, they fixed their feet firmly in the place they occupied, and crept out, leaving the empty skin in its

natural form, so that at the first glance you would swear the little animal was still standing there.

"Now," says Friedel, "As I read this, it can scarcely be told how saddened I was, for the hope I had previously conceived was falling into ruin." The account of Gædart did not really seem to confirm the hypothesis about the cochineal, for there was no description of any stage that really corresponded to the grain. Friedel was about to change his opinion in toto, when he "had another reasonable suggestion from the most excellent Dr. Lang, to whose most faithful training I owe almost everything in the course of my medical studies." For as Dr. Lang was the first to suggest to Friedel the theory about the nature of the cochineal which formed the subject of this thesis, so he now came to the rescue with facts and experiments concerning the German ladybird "depicted as in life with an elegant brush in colors, and most accurately noted from day to day," all of which, in the year just passed, Friedel was permitted to observe and confirm with his own eyes.

Sure enough, in the month of June, on the upturned leaf of the greater nettle, are seen very tiny egglets of a saffron color, adhering firmly. As may be seen in our illustration, letter *g*, from these, a little later, are spontaneously hatched blackish oblong little worms, below the size of a flea, but equipped with six feet on the anterior part of the little body, see letter *h*. These little insects are sluggish for some time after their birth, and scarcely move from their place; until, after the lapse of several days, they acquire the necessary strength, and running hither and thither, gather food, so far as we can see, from dew. [They feed on aphides, but Friedel neither observed this, nor considered the fact that mere dew was rather unsustaining!] After about three or four weeks have elapsed, they reach a size such as is indicated under letter *i*. At this time, they are elegantly ornamented on the sides with several yellowish spots, and their color, dark before, is changed to an ashen hue, especially along the middle of the back. Now this fleet-footed worm prepares itself for a metamorphosis, wandering more tardily at first, soon hardly at all; and then, affixing itself by its tail to a leaf, is wrinkled up as shown under letter *k*. By degrees the covering drops off to the rear, and it passes into the pupa or nymph, of which the anterior and posterior aspects are shown under letters *l* and *m*. The insect, even in this state, still lives, as may be learned from its movement when touched. It remains thus until the tenth and not rarely the twelfth day, when the covering is broken, and there comes forth, the skin being left motionless, a beetle, which at first is rather weak, and whitish, but changing in a few hours to yellow or red, the black spots coming into view on the elytra.

This is really an excellent account of the ladybird, excepting only the error as to its food, and from these observations Friedel felt encouraged to believe that he had put the finishing touches on his theory of the cochineal; for was not the ladybird pupa just like it? "But," says he, "if perchance this should still seem doubtful, here is a further observation to confirm it. When a friend, addicted to trade, gave me at one time a large enough heap of cochineal to examine, I

found mixed with it several worms, not yet altogether changed into pupæ, of a color which from ashen was becoming purple, and which when immersed for a while in water, assumed the form seen in the engraving under the letter *C*. Hence there came to me the suspicion that under this form appeared the worm of the cochineal before giving itself to rest; for that it certainly belongs to this family, I am persuaded by the purple color which it discharges into the water in which it is immersed, just like the cochineal itself. For when all the eggs of these insects are not hatched in one precise day it at least becomes probable that neither are all these worms in one moment transformed into pupæ, or the beetles simultaneously creep forth from these. So, without doubt, when the harvest of pupæ is at hand, several of these worms, which have not yet reached the pupa state, and also several adult beetles, are shaken off at the same time from the tuna. Consequently, we usually find them all mixed, in more or less abundance, with the best cochineal." The worms thus found may be the true larvæ of the ladybeetle, or in other cases, the larvæ of certain two-winged flies of the family Syrphidæ, which also prey upon the cochineal. The presence of the flies is especially indicated by another observation of Friedel's—that he found even a few cup-shaped objects, in which were occasionally seen some small grains of cochineal. Here, he thought, were actually the skins left empty after the exit of the beetles; but on further reflection he abandoned the idea, as they really were not large enough to hold the beetle. The grains found in them were very minute, and were doubtless only cochineal larvæ which had wandered in by accident; and finally, some of these cups still contained, not a beetle, but a single fly. These were, we may now rest assured, the puparia of a predatory Dipterous insect, either a Syrphid or a species of *Leucopis*.

By the time of Linnæus, some fifty years later, it was clearly known that the cochineal had nothing to do with the beetles, but belonged to the Hemiptera. Even then, however, it seemed fated to be a source of error and misunderstanding. When Linnæus was preparing his great "Systema Naturæ," a friend of his, Daniel Rolander, resident in the West Indies, sent him what he supposed to be unusually fine specimens of the cochineal alive on a piece of cactus. Linnæus naturally used these in making his description of the *Coccus casti*, and until 1899 nobody seems to have suspected that they were not the real cochineal. However, Rolander sent some at the same time to DeGeer, who figured them, and from the account he gives, and indeed also from that of Linnæus, it is evident that the *Coccus cacti* L. is no cochineal, but a species of a quite different subfamily, which, curiously, has never been found by any entomologist since it was discovered by Rolander.

NOTES ON THE DEVELOPMENT OF TELEPHONE SERVICE

BY FRED DELAND

PITTSBURGH, PA.

XIV. TELEPHONIC AND FINANCIAL CONDITIONS, 1880-1883.

FOLLOWING are the Bell statistics for the four years, 1880-1883: On March 1, 1880, there were 138 Bell telephone exchanges, in operation or about to open, while a year later the number had increased to 408, a net gain of 270 exchanges, or of nearly 200 per cent. Though only three years had elapsed since the first of these pioneer exchanges was opened, on March 1, 1881, 66 exchanges were interconnected by toll lines, Boston had toll communications to seventy-five cities and towns, the total number of places for which licenses to build exchanges had been granted was 1,523, and thirty-two contracts had been given to build connecting toll lines. But, these 408 exchanges supplied telephone service to only 47,880 subscribers located in 463 cities, towns and villages, or an average of only 117 subscribers to each exchange.

At the close of the year 1881, the number of Bell exchanges had increased to 592, with a total of 70,525 subscribers, located in 1,593 cities, towns and villages, while the average number of subscribers per exchange had increased from 117 to 120.

On December 31, 1882, there were 1,070 Bell exchanges in operation, a net gain of 478 for the year, or of 81 per cent. This growth represented an average increase of two new exchanges for nearly every working day in the year. Yet the total number of subscribers was only 97,728, or an average allotment to each exchange of only 91, that is, 29 less subscribers than the average of the previous year. The handiwork of the speculative builder of small exchanges, grasping for quick profits, is here indelibly imprinted on the records. In the large exchanges the high flat rate limited the growth to the wealthy in the resident districts and to the larger business houses and professional offices where telephonic communication was an absolute necessity. This seems a reasonable conclusion to draw from a growth of only 38 per cent. in subscribers and of 81 per cent. in exchanges.

And the record for 1883 is of the same delusive character. On December 31, there were 1,325 Bell exchanges in operation in 46 states and territories, supplying service to 123,625 subscribers, and giving employment to 4,762 persons. In other words, there was an average of nearly four employees to each exchange, though the aver-

age number of subscribers connected was only 93. And as there were many exchanges having more than 300 subscribers, it is obvious that many others had less than 30, and thus were being operated and maintained at a continuing loss.

What were the financial conditions of the country during these four years, 1880-1883? What was the character of the sentiment prevailing among investors that enabled such anomalous conditions to continue?

The year 1880, notwithstanding that a presidential election occurred, proved to be an admirable period for the promotion of industrial as well as speculative enterprises, and telephone projects of every character appeared to meet a hearty welcome at the hands of the investing public. To the older licensees, enriched by the wisdom gained in a whole year's experience, it soon became evident that many of the new exchanges were being built and operated only for speculative purposes by local promoters, in anticipation of profitable consolidations, rather than as a permanent investment for local capital. For the question of equitable rates yielding a fair return on a legitimate investment, or the unpleasant results in lowering the character of the service by giving unlimited calls at an unprofitable rate, thus loading the lines with gossip and frivolous conversation, to the detriment of rapid, legitimate service, did not concern the speculator. Where the older licensees endeavored to warn local investors against accepting the speculator's statements without substantial proof, the latter felt justified in agitating a public denunciation of what he termed the extortionate rates of the older licensees. The natural result was that the speculative exchanges had a big list of subscribers at unprofitable rates, until consolidation brought a new management that proposed to take care of the shareholders first and then give the best service possible to the subscribers. This meant an increase in rates to an amount that would insure a fair return on the investment; and then fully one half the subscribers who had been reaping the advantage of unprofitable rates promptly displayed their gratitude by giving up the service rather than pay the increased price.

On January 21, 1881, many of the telephone companies in the east suffered from the most destructive sleet storm that had visited that section in a long period. So great was the weight of the sleet frozen on the wires attached to roof-fixtures that in numerous cases the roofs were wrecked and walls were damaged. Miles of the pole lines went down, and in the main thoroughfares of the larger cities telephone wires were inseparably entangled with telegraph and electric light circuits. By reason of modern methods of construction, a disaster of such a character could not now occur, though greater losses have occurred in several sleet storms. But this was the first serious wreck

of the kind that the new telephone industry had had to face, and its disastrous outcome was exceedingly discouraging. The immediate loss to the New York company was nearly \$100,000, while the indirect loss in delaying extensions and improvements and in diverting investment from the treasuries of the injured companies was very large.

The only remarkable change in financial circles occurring in 1881 was the flurry in the stock market that followed the assassination of President Garfield on July 2, 1881. To the far-sighted financier that "agitation approaching a panic" may have indicated the beginning of the general depression that gradually overspread the country and proved most severe in 1885.

On July 14, 1881, the New York *Tribune* editorially asserted that the agitation that caused the flurry was utterly without foundation and that the proportion of business done upon a cash basis is larger than ever, and the proportion of business done without borrowing, on the capital of the firms engaged, is larger than ever. . . . Nor has there ever been a time when the earnings of the people were on the whole as large as they are now. Wages are good, while prices are relatively low.

But from the telephone speculator's point of view, the ill effect of that July flurry was more than offset, so far as the investing public was concerned, by the admirably wise and now famous telephone decision rendered by Judge Lowell on June 27, 1881, in the suit begun on June 22, 1880, in the Eaton-Spencer case. In part that opinion read as follows:

If the Bell patent were for a mere arrangement, or combination of old devices, to produce a somewhat better result in a known art, then, no doubt, a person who substituted a new element not known at the date of the patent might escape the charge of infringement. But Bell discovered a new art—that of transmitting speech by electricity—and has a right to hold the broadest claim for it which can be permitted in any case; not to the abstract right of sending sounds by telegraph, without any regard to means, but to all means and processes which he has both invented and claimed. . . . The claim is not so broad as the invention. . . . An apparatus made by Reis, of Germany, in 1860, and described in several publications before 1876, is relied on to limit the scope of Bell's invention. Reis appears to have been a man of learning and ingenuity. He used a membrane and electrodes for transmitting sounds, and his apparatus was well known to curious inquirers. The regret of all its admirers was, that articulate speech could not be sent and received by it. . . . A century of Reis would never have produced a speaking telephone by mere improvement in construction.

President Arthur proved a worthy successor to the lamented Garfield, and his strong and conservative policy appeared to win the confidence of the people, many of whom had been led to expect a more radical and less safe administration. Thus the year 1882 opened

auspiciously for all speculative interests. But in February came the notorious break in Richmond and Danville, from 219 to 130, that flurried the stock market and increased the general uneasiness concerning all investments. Nevertheless, the total volume of business transacted throughout the country during the year was very large, no less than \$350,000,000 being expended in new railroad construction.

The general financial and commercial conditions that prevailed during 1883 may be summed up as follows: There were 9,184 failures with aggregate liabilities of \$172,874,000, as against 4,735 failures in 1880 with aggregate liabilities of only \$65,752,000. Not only was there a large decrease in the total volume of trade, making retrenchment in nearly every line of industry an imperative necessity, but a general distrust of the integrity of all stocks and all bonds prevailed, with a consequent enormous decline in the market values of many securities, including even those of the new telephone consolidations. An eminent financial writer in referring to the speculative fever that had raged during the previous two years, 1881-1882, declared that:

Our whole people became wild upon the subject of railroad construction, believing that two or three dollars could easily be made for every dollar put up, either by the success of their ventures or by the sale of their securities. In this delusion the capitalist and the adventurer shared alike.

Nevertheless, notwithstanding these discouraging conditions, or the gloomy outlook for the coming year, or the nine thousand failures in other lines of business, or the low market value of the stock of certain large licensee companies organized to absorb the handiwork of the speculator as portrayed in numerous small and unprofitable exchanges, the art of establishing new telephone exchanges, especially in small towns and villages, progressed even more actively in 1883 than ever before. So many investors believed that it was only necessary to establish any kind of an exchange in any kind of a village, no matter how small or how unprofitable the rates might prove, to secure profits of three for one, that the editor of an electrical journal wrote: "No fable concerning the telephone is too gross to receive credence; no prediction of its future can be wild enough to provoke a smile." And the daily papers fed this delusion by constantly referring to millions of dollars alleged to have been made in the telephone business, although the parent company had paid no cash dividends prior to January, 1881, all of which statements many readers accepted as applying solely to exchanges established in small villages, just as three years earlier many investors believed that large profits would be derived from building small branch railroads. And had it not been for the many investments made by farmers in railroad securities, in the aggregate amounting to several millions of dollars, from which no return was secured in many cases, it is quite probable that the farming community

would have developed a rural system of telephone service contemporaneously with its early growth in towns and villages.

Again, the infringing telephone companies, and they were numerous, while their promoters were strong in political and financial influence in the '80's, circulated the most absurd statements concerning the millions that had been made in the consolidating of Bell operating companies, and the manipulation of telephone stocks. One statement read: "It is within limits to say that the entire property, rights and franchises of the Bell company and its licensees could be duplicated for one twenty-fifth of the stock capital invested." Yet it is interesting to note that during the three years, 1881-1883, in New York state alone, one hundred and twenty-five infringing telephone companies were organized and capitalized at an aggregate of two hundred and twenty-five millions of dollars, a capitalization authorized by one state only, and three times greater than the combined capital stock of all the Bell companies in all the states of the union, including that of the parent company.

Very fortunately for the investing public, few of these infringing companies ever got fairly under way, even when the highest officials in state and nation appeared to do all in their power to aid in filching rewards honestly won and meritoriously bestowed. Moreover, it has been stated that many of these infringing claims were offered to the parent Bell company for small sums or large sums, depending upon how gloomy or how roseate the outlook was. A comical phase of these infringing competitive schemes was the certainty with which statements would appear in printed circulars, that the telephone was first exhibited to the public at the Centennial Exposition in 1876, and the first telephone line was constructed in Boston in 1877. The fact that they thus admitted that Alexander Graham Bell's telephone was the first telephone did not appeal even to their sense of humor.

Even the announcement on January 24, 1883, of Judge Gray's decision on final hearing in the Dolbear case, and of Judge Lowell's decision the following August, did not appear to discourage investment in the securities of infringing companies, while both decisions served to stimulate the building of small exchanges by speculative promoters and the rapid consolidation of these non-paying properties into over-capitalized organizations.

Judge Gray's opinion in part was:

The opinion in Spencer's case clearly points out that "Bell discovered a new art—that of transmitting speech by electricity—and has the right to hold the broadest claim for it which can be permitted in any case." . . . The evidence in this case clearly shows that Bell discovered that articulate sounds could be transmitted by undulatory vibrations of electricity, and invented the art or process of transmitting such sounds by means of such vibrations. If that art or process is (as the witnesses called by the defendant say it is) the only way

by which speech can be transmitted by electricity, that fact does not lessen the merit of his invention, or the protection which the law will give to it. . . . Whatever name may be given to the property, or the manifestation, of the electricity in the defendant's receiver, the facts remain that they avail themselves of Bell's discovery that undulatory vibrations of electricity can intelligibly and accurately transmit articulate speech, as well as of the process which Bell invented, and by which he reduced his discovery to practical use; that they also copy the mode and apparatus by which he creates and transmits the undulatory electrical vibrations, corresponding to those of the air.

On August 25, 1883, the opinion of Judge Lowell on final hearing was delivered in part as follows:

I decided in *American Bell Telephone Co. v. Spencer*, 8 Fed. Rep. 509, that Reis had not described a telephone which anticipated Bell's invention. The same point has since been decided in the same way in England. *United Telephone Co. v. Harrison*, 21 Ch. D. 720. It is admitted in the present case that the Reis instrument, if used as he intended to use it, can never serve as a speaking telephone, because the current of electricity is constantly broken; and it is essential for the transmission of speech that the current should not be broken. The defendant (Dolbear) now testifies that the Reis instrument can be made to transmit speech, under some circumstances, if operated in the way which Bell has shown to be necessary. In 1877, he several times expressed the opinion that Bell made the invention, and that Reis did not make it. The experiment made in the presence of counsel, which was intended to prove the correctness of the defendant's present opinion, was an utter failure. . . . At the former hearing in this case before Mr. Justice Gray and me, we decided that the defendant (Dolbear), whatever the merits of his telephone may be, employs in it a part, at least, of Bell's process. No additional evidence has been given at the final hearing, unless a further explanation of that already given may be called additional; and I remain of the opinion expressed by the presiding justice at that time.

Telephone men were not alone in their realization that self-preservation lay in concentration. For financiers were beginning to perceive the wisdom in the original plan of one great company, to also realize how dependent the future growth and development of the industry was on a centralized policy, and to foresee that the product of unity in purpose, in method, in management, would be serviceable to users and profitable to investors. It was already evident that telephone service had come to stay, that it was an important aid in the transaction of business in every line of industry, and that it was certain to have a revolutionizing effect on many phases of industrial, commercial, professional and social life.

In its annual report for the fiscal year ending February 28, 1883, the parent Bell company said:

From the local companies throughout the country the reports are encouraging. Most of them are now earning and paying dividends, and extending their business with energy. An important feature has been the consolidation of local telephone interests into large companies, covering many counties, and even in several instances the whole or the greater part of entire states. This policy has

been assented to so far as its adoption seemed in the interest of convenient and economical management, but it should not be encouraged to an extent that would leave these companies entirely in the ownership of persons who are not residents in the territory where the business is carried on. It has always been our policy to keep local capital and influence interested in the business as far as possible, and to this course may probably be attributed a good part of the success which has attended the development of the business.

A year later the parent company reiterated the foregoing conclusions concerning care in consolidating companies and added:

In spite of the prevailing opinion that the development of the telephone substantially under one control is against public interest, we believe that an intelligent examination of this question would demonstrate that this is not true and that in no other way could the desired results be obtained and the difficulties be surmounted so rapidly and so well as by the present one.

Like the previous year, 1883 was a year of mergers; and when this two-year period closed, the number of Bell companies had been reduced, through absorption or consolidation, from several hundred to less than one hundred, and the parent company was gradually getting into a position where it could strongly influence the policy that should prevail.

In some states practically all the exchanges were absorbed by one strong company; in other states three or four companies aided in bringing about the consolidation, and then divided the territory. For instance, in the summer of 1882 the daily papers told how:

New York and Philadelphia capitalists are visiting various sections of Pennsylvania with a view to consolidate all local telephone companies between New York and Pittsburgh into one general organization, with main offices in New York, Philadelphia and Pittsburgh.

While the promoters failed in consummating so big an undertaking, their efforts paved the way for consolidations more limited in scope. In Massachusetts a combination known as the Lowell syndicate was quite successful in consolidating many exchanges, some of which will be more fully referred to in a following chapter.

Referring to the numerous consolidations of small local licensee companies into new organizations chartered to work on broader plans, the parent Bell company in its annual report for 1883 stated that:

the tendency towards consolidation of telephone companies noticed in our last report has continued and is for the most part in the interest of economical and convenient handling of the business. . . . As methods are devised for making the telephone commercially useful over long lines, the advantages of this centralization of management will be still more apparent, as well as the importance to the public of having the business done in large territories under one responsible head, with far-reaching connections throughout the whole country. To make this service of the highest value to the people will be complicated enough under one control. Were it in the hands of many competing companies, the confusion resulting would be very serious, as the value of the telephone will be largely measured by its capacity to give prompt connection with all parts of the country.

The parent company also held that the securities issued by its operating companies ought to represent legitimate values, not speculative or estimated values based on what the plant might earn in the future; that the intrinsic value of the telephone securities should be made clearly apparent to investors, and that the established integrity of the investment should be maintained by providing ample sinking-funds and reserves to cover every contingency. Its expressed policy was:

to encourage payment of dividends by local companies with a view to getting local influence and capital interested in telephones, but it never encouraged the payment of dividends except when earned.

Such conservative methods were not in accord with the sentiments of speculators who preferred to experiment with the credulity of thoughtless investors, so long as such experiments yielded rich profits. The people believed the newspaper stories about the fabulous profits small telephone exchanges were deriving from limited investments. Then why destroy such honest beliefs by presenting cold facts? Consolidation of exchanges was a good thing; it meant large profits for the promoters.

When these local exchanges were transferred to the management of the new organization, it was quickly perceived that many subscribers were receiving service at rates involving constant loss to the company, as already stated. An increase in rates naturally followed, which, in turn, resulted in some of these low-rate subscribers discontinuing the use of the service. Sometimes from 25 to 50 per cent. of the subscribers to these consolidated exchanges would drop out, and the loss in the income anticipated from these subscribers upset many plans. For most of these new organizations, in expectation of being able to readily dispose of the new securities, had proceeded to reconstruct the old plants absorbed with a view to giving a higher class of service and of promptly and properly handling a large increase in the number of subscribers. To meet the indebtedness thus incurred it was necessary either to sell shares of stock at a price considerably lower than the authorized price, or else to settle the indebtedness with the funds set aside for dividend payments, and in lieu of cash payments to shareholders to issue stock dividends. Again, this inability to raise the funds necessary to make needed extensions and improvements and to keep pace with the growing demands of the public, meant that for an indefinite period the gross earnings must provide for all construction and reconstruction, as well as for the operating and maintenance charges. In other words, in 1883-1886, until improved financial conditions permitted the sale of telephone securities at reasonable prices, growth and progress were necessarily limited within narrow lines that yielded sure returns to the holders of stock certificates.

THE HEALTH OF AMERICAN GIRLS

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IN a paper, 'Alumna's Children,' published in this magazine in May, 1904, the wish was expressed that some one might determine how far 'the way in which our girls go to school' governs their health in later life. This article is an attempt to consider that question. To any one familiar with all that has been written on the health of American women the subject must seem exhausted in one sense at least. As one reads the different monographs giving the cause of woman's physical weakness, each writer dwelling upon some one condition which is of itself entirely sufficient in his opinion to overthrow her health, one can but think of the man who committed five murders and was condemned to be put to death five times. Yet perhaps there is a word more to be said. A large proportion of the papers have discussed college students or adult women and almost every serious consideration of the health of the schoolgirl has been by a physician and necessarily from his point of view. A girl is more fully and more normally known to her mother and her teacher than to her doctor; they observe all the influences of her life as he can seldom do. For some reasons a wise mother would seem to be the one best fitted to speak on this matter; she should know more intimately than any one else the nature of her daughter. But the mother is limited to the conditions that have operated in her own family. The daughter's teacher learns the personality of the individual girl with a thoroughness second only to that of the mother and she knows just as intimately scores of other girls who have grown up under vastly different conditions, so that she is able to draw general conclusions as the mother of one or two can not do. I have not come upon any full discussion of the health of our girls from the teacher's point of view; it is this that I shall try to present.

The delicacy of our American women, noted abroad and admitted at home, is coming to be a tremendously vital question. The condition apparently is peculiar to no class and it appears in the second generation of other nationalities immigrating here. Lack of fecundity is only one of its indications. Does it not seem to you that most of the women whom you know confess that they are 'not very strong'? Nervous exhaustion and what the newspaper advertisements call 'womanly weaknesses' are the most common ailments, but there seems to be in women far more often than in men a lack of general vitality, an inability to resist disease.

This state of affairs is generally admitted, but there is no evidence that it was nature's original plan. On the contrary, there is reason to believe that the woman was meant to be quite as strong as the man; nature has ordained the hardest tasks for her, and has given her a wonderful equipment for them. Among primitive races the woman is fully the equal of the man in strength, his superior in endurance. Superior in endurance in certain respects she remains even under modern conditions, as dentists and surgeons bear testimony. But where has gone the vigor that she requires to meet the demands that life makes of her? Is it the schools and the teachers that are responsible for its loss?

I was moved anew to thought on the subject by seeing last June the Ivy-day procession of a woman's college and the next week the graduating exercises of a large high school. The college girls looked notably robust, sunburned as to cheeks and arms and hair, but attractive for their evident health. They seemed far above the average American women in their physical vigor and did not lead one to believe that a college education makes invalids. The girls in the high-school class—the man beside me, himself the father of one of them, expressed their appearance adequately though bluntly when he said, "Those girls are a puny-looking lot." The characterization was true of that class; is it true of the average high-school girl? Consider the question for yourself as you see in June the graduates of your local high school. And those before you are the fittest who have survived; they are very few in number compared with those who have dropped by the way.

Ten years ago I read an unforgettable paper written by a high-school senior. She was a brilliant student who, maintaining the highest rank in her class, had done the preparation for Radcliffe, but had given up any hope of a college course because she was completely broken in health. Her essay was a scathing arraignment of our public-school course; I have been trying ever since to determine how far it was just.

Discussion of the health of the students in women's colleges is always a popular subject; has due attention been given to the physical condition of the young girls in the public schools? The public schools are of course immeasurably more important than the colleges. From the beginning of our national life great sacrifices have been made for the maintenance of our schools, sacrifices are still being made. They are expensive in money; in most of our towns no other appropriation is so large as that for education. They are also costly in the men and women that they use up, the teachers that they suck dry of health and strength and throw aside. The teachers seem to think that the work is worth their sacrifice; the tax-payers give ungrudgingly for their children. But if the physical vigor of the children or of a part of the children is one of the expenses of the public-school system, then popular education is costing too much.

The school system is a manufacturing plant and as such its efficiency is properly judged by its output—that is, its graduates. These are subject to physical examination as properly as to mental examination. The boys in the last years of the high school seem encouragingly robust. They usually take a little lower rank in their classes than do the girls, but, as they would themselves express it, they do their work ‘well enough’ and when their lessons are done they have supplies of unexpended energy. In athletics they show considerable endurance and many boys partly support themselves by working in shops and offices outside of school hours. In their own homes they prove active, hungry and without excess of nerves.

The condition of the average girl is manifestly different. She appears to the casual observer anæmic, flat-chested, round-shouldered and out of symmetry, and a member of her family knows that she is fickle of appetite, regularly subject to headaches, nervous and irritable. Some of the girls are frivolous, devoted to ‘society’ and to trashy novels; the average is conscientious about her work and almost morbidly painstaking. She worries over every lesson until it is prepared as well as she can do it, probably after that because it is not done as well as some one else could do it. Her study—and her worry—exhaust her and any other work is a burden. At best she needs complete rest after graduation; at worst she joins, perhaps for life, the ranks of the women who are not strong. A large number of pupils leave the high-school before completing their course. More boys than girls drop out, it is true, but the boys go to earn a living or because they have not met the requirements of the school. The girl very often goes by her physician’s advice.

If we consult a doctor for an ailing high-school girl he makes a diagnosis and a prescription almost at sight—“over-study; take her out of school.” Often he does not find it necessary to inquire about any other habits of hers except her habit of study. But is her going to school the chief factor in the girl’s breaking down? If so, things were better managed in the days of our grandmothers when no girl had much public schooling after she was fourteen years old.

If a girl breaks down under a course of study on which a boy thrives does it indicate that she has less mental power? We dislike to admit it and the experience of our teachers does not in general indicate it. Why should we attribute the widely different result to the one thing that is exactly alike for both sexes? Brother and sister come into the world with the same mental and physical heritage. The girl inherits tendencies of body and mind from her father quite as much as from her mother. The boy and the girl have the same food and the same course of study. At the high-school age the development of heart and lung and brain is at about the same stage in both sexes; the girl is a little nearer to her adult weight and height. What circumstances

of their lives have been different for them? When do they begin to show differences in themselves? From a very early age there have been certain differences—in clothes, in occupation and in recreation, but these have manifestly been superficial and insufficient to account for the contrast. Very little difference appears between the sexes until they are nearly through the grammar school. Then a great change comes to the girl. "My daughter has become a woman" is the phrase which our grandmothers used to describe the epoch; and far as the callow, fourteen-year-old maiden seems from womanhood, the term is the exact expression of a vital truth.

It is at this very beginning of woman-life that especial attention is needed. We know that the boy who is overworked before he gets his growth is always an undersized man; just as surely a girl who is overworked physically or mentally during her period of puberty is always an undeveloped woman. And mental overwork is fully as injurious as physical overwork.

To speak plainly, the maturing girl must have blood and vitality to perfect the organs essential to her complete being and to establish regularly the periodic function characteristic of her sex. She must do these things at the time appointed. If she must choose between developing mind or body let her by all means choose nourishment for her physical growth. The mental expansion can come later, but the physical perfecting has no second chance. If there is lack of development or unbalanced development at this time she is pretty sure to endure suffering for the best part of her life. From careful investigation of the physical condition of a large number of girls it has been found that from "65 to 70 per cent. enter the higher institutions of learning and business with menstrual suffering of some sort." In some occupations the rate of suffering is as high as 91 per cent.

And the girl may be called upon to bear other sorrows harder than pain for a woman to endure. The injury from arrested development may not appear at once, though flat chest and narrow hips may suggest it; but when life demands of the woman that she do a woman's work she is unequal to it and is broken down in her attempt. Dame Nature, herself the representative mother, has her own idea of the function of women in the scheme of things. When they are fulfilling her purposes she gives them marvelous protection, but woe to those who try to stand against her!

Just as soon, then, as signs of change appear in the girl she should have especial care. To quote from Dr. Engelmann, "She should have personal talk and explanation from a woman who has learned the meaning of wifehood and maternity." To supplement from President Hall, "The quality of motherhood has nowhere a more crucial test than in meeting the needs of this epoch." In general the girl should have at this time no mental or nervous strain to divert nourishment from her

physical development. At best, if she is strong, does her work without worry and "normalizes her lunar month" promptly, she may stay in school without much danger provided she take her two days of rest periodically. I am inclined to believe that this is in all cases worth while until the end of the high-school course, although it is always impracticable to make general rules. A number of women who consider themselves perfectly well so far as sex weakness is concerned have told me that they believe their health due to their year of complete rest at puberty and that they did not find the need of monthly rest after the first years.

I am coming to be convinced, somewhat against my wish, that there are many cases when the girl ought to be taken out of school entirely for some months or for a year *at the period of puberty*. This course is supremely worth while if she shows irregularity of function or decreasing vitality, and it is at this time that there is profit in such an especial vacation.

I do not speak with ill-considered lightness of taking the girl out of school for a year. It is a serious matter to her at a time when she is likely to take all her life too seriously and when she should feel as free as possible from annoyance. She is naturally disturbed at leaving her class, especially if she is likely thereby to lose a grade. It is worth while to take considerable pains to minimize her distress. If she enjoys a pleasant visit out of town until the term is well under way, then returns to private lessons with her mother or some other wise teacher, lessons determined in time and length by her physical condition, she may endure her enforced vacation from public school without much fretting. The anxieties of this period ought to be borne for her as far as possible; that she should become anxious about her own health would defeat the very end in view. She can be assured that days out of school now are pretty sure to remove the necessity of days or weeks or months out of school later in her course. Similarly two days out of school every month the first year that she is in the high school in order that she may not suffer are really much better worth while than two days out of school the last of the course because she is not able to be present. These days of rest are not in the least incompatible with good work in school; a girl so cared for may be expected to accomplish more in a year than she who has no such restraint. Mothers protest again and again that such a custom is entirely incompatible with modern school demands, but I have never known a teacher to say that it was not quite practicable, and I have seen school work done under this régime to the entire satisfaction of all concerned. It is perhaps worth while to record here the questions of one grammar-school teacher—"Why will not mothers tell me when the critical period begins for their daughters? Many times I can determine for myself, but in general I could make things so much easier for the girls if I could only know when they need especial indulgence."

No, the objection to periodical rest does not come from the teacher nor primarily from the mother, but from the girl herself. Yet if our thoughtful mothers could be convinced that "the health of a girl for her whole life depends upon her normalizing the lunar month," to employ a phrase of President Hall's that I have quoted before, they would bring about the best order of things. But most mothers honestly believe that no great care is necessary. They expect their daughters to get along about as well as they did and they suppose that about so much pain is necessary for women. Mothers could hardly escape being convinced of the great responsibility that is upon them at this time if all the evidence that exists on the subject could be brought to their attention.

It is undoubtedly true that each month in a woman's life is a continuous wave with a regularly recurring succession of phases and this continuity of change makes an ingenious argument that a woman does not need especial rest at any particular time of the month. But my own observation would have convinced me that it is supremely worth while to guard an adolescent girl from nervous strain during the days when the wave of her vitality is at its lowest point even if physicians and educators had not spoken so strongly in favor of the custom. Dr. Mary Putnam Jacobi, in the monograph which she wrote to show that there is nothing in the physical nature of the adult woman to incapacitate her periodically for work, says nevertheless, "In adolescence and during the first years that the reproductive wave of nutrition is being formed mental work exacted in excess of the capacity of the individual may seriously derange the nutrition"; and elsewhere in the same paper she says, "It is curious to note how the effects of misery and the effects of luxury during the childhood of a girl are found so often to result in an identical mode of stunting during adolescence."

Much that has been written on the subject of puberty in girls has been printed only in medical and educational journals. Perhaps some women of delicacy may say that the discussion of such a matter is properly confined to medical journals. To a certain extent this is undoubtedly true; the trouble is that the average mother does not have easy access to those files. Therefore it seems worth while to quote at some length in this paper.

The idea that a girl needs especial care at her time of maturing is not a new fad of educators. In the time of Hippocrates it was noted that the period of puberty was very critical for the development of the nervous system. The rites enjoined by Moses provided for the care of the girl at this crisis and a similar provision appears in the code of Zoroaster. Savage nations to-day prescribe and protect by their superstitions definite observances for the woman at every period of her sex-life from the beginning to the end. The women of the North American Indians, always regarded chiefly in reference to their utility,

nevertheless have assured to them by custom from three to five days every month so long as the monthly law rules them.

With the present increased attention to the study of preventive medicine, students of gynecology have come to believe that the diseases of women are in good part due to their "ignorance of functional hygiene." In 1901 Doctor Engelmann gave as his president's address at the annual meeting of the American Gynecological Society a paper, "The American Girl of To-day," which entirely covers this subject from the physician's point of view. In brief his opinion as there expressed is: "Adolescence is the most important period of a woman's life, the period during which the foundations of future health are laid. It is in this period of school, the beginning of social life, the period of learning in trades that the nervous energies of the female are most fully engaged and her activity is concentrated on the brain to the detriment of other functions, above all the developing sexual function, the central and most important and at that time the most easily disturbed."

Dr. Wylie has expressed his opinion that "the American horse receives on the average better treatment than the young women of America from the time of early girlhood until the age of development is passed."

President Clark and Professor Tyler have studied systems of education with especial reference to the physical development of children. In his book 'Adolescence,' President Hall devotes a long chapter to the subject of 'Periodicity.' He is himself convinced that the health of a woman for her whole life is determined in her days of adolescence, and he cites so many witnesses, ancient and modern, learned and savage, that the most unbelieving reader can but be convinced while she reads.

Professor Tyler, as a student of biology and education, has considered what bearing the laws of growth have upon the proper arrangement of courses of study. In his lectures on 'The Physical Basis of Education' given last winter in Boston before the Twentieth Century Club he said, concerning the development of girls during their school years, "At the critical period of puberty almost every organ in the girl's body is affected. [The girl's] pubertal period is much more likely to be stormy than the boy's and her rate of morbidity is considerably higher. Her future health and happiness, if not her life, depend upon the successful completion of the metamorphosis."

A valuable addition to our knowledge of schoolgirls has been made by Dr. Helen Kennedy. She collected statistics of the habits and the health of girls from a large city high school; her article includes her questions and the answers of the students, so that we may draw our own conclusions. We note that while nearly all the girls report themselves as growing no worse during their high-school course, 97 out of the 125 say that they suffer to a greater or less degree. All Dr. Ken-

nedy's results are interesting and full of suggestion, and much light upon the health of our women would come from further investigations along these lines. From her data and that of others, it is to be noted that most girls between sixteen and twenty suffer more or less; and that alike for students and working girls the percentage of sufferers increases during that time.

My belief that most girls have the foundation of their suffering laid before they are sixteen may be unwarranted, but I have found no data that contradict it. Quoting again from Professor Tyler, "The critical period in a girls life is evidently the years between ten and fifteen, earlier than most of us think. Most of our care and thought is devoted to locking the barn door after the horse has been stolen." And once more, in the phrase of Dr. Engelmann, "the younger the girl, the nearer the period of puberty, the more impressionable the system, the more susceptible to influence for good or evil and most harm is wrought in the first year of functional life." I quote much from Dr. Engelmann, but where can I find better authority, especially in this particular phase of gynecology?

I have given a large part of my discussion of the health of our girls to a consideration of the demands of sex at adolescence, but perhaps this extent in treatment is not disproportionate to its importance in their lives. When a girl is safely guided "through the breakers of puberty" we have some reason to expect for her life-long vigor and the power to do. But she needs also through the rest of her school days intelligent direction in other respects. It sometimes seems to the teacher that she does not get quite as much as she needs.

The teacher is expected to see all that goes on in the schoolroom; in addition to this she does see evidences of a great many things that go on outside the schoolroom, things which, though they largely affect the results of her work, she has little power to modify. The personal habits of a girl determine to a great extent what she is able to gain from her course of study. If it is important that her nourishment be directed at all times to the most immediate needs of her body, surely it is no less important that there should be sufficient nourishment to satisfy these needs.

Every girl knows that this sufficiency of nourishment is impossible unless she assimilates plenty of food, but she does not always make her knowledge evident in her habits. Very often the high-school teacher is asked to excuse from the session, on account of headache, some girl who admits when questioned that she has eaten no breakfast that morning. It is possible for the teacher to point out to the girl the folly of starting a locomotive for a day's run without providing fuel, but the girl must have some pressure brought to bear upon her at home if she is to take sufficient time for her meals. Insufficient breakfast is

often due to late rising; if the girl has not time enough to dress and to eat, it is not the dressing that is hurried.

With the usual five-hour high-school session the girl needs at recess a proper luncheon. If the school has a lunch counter where only suitable food is provided, then it is well, but in case the luncheon comes from home the teacher often wonders whether the mothers are accessory to the mince and lemon pies and the fruit cakes that make the daughters unfit for study. At the end of the long session the girl comes home with little appetite or power of digestion. In a working-man's family dinner was served more than an hour before, and the plateful of food that has been kept warm for the daughter is hardly palatable; probably she makes her meal chiefly out of the dessert. It is tremendously worth while for the mother to preside personally at this meal of her daughter and always to have tempting, nourishing and easily digestible food ready for her when she comes home from school.

The blame for a high-school girl's dyspepsia is often attributed to the one-session system; and under that system a bad order of things is easy, as we have seen. On the other hand, with one session very much better conditions are possible than with two if the best use is made of the time out of school. It ought to be possible for the greater part of the pupils to work under better conditions at home than in most schoolrooms; and when they are in school until four there is little time for being out of doors in the sunlight during most of the school year.

The girl who is insufficiently nourished craves abnormal things and eats sweets and sour in unsuitable proportions. With all these sins against her digestion much of her food is not assimilated. Very often the waste is not properly eliminated; the girl does not realize that this condition is a menace to her health and so her whole system is poisoned. Constipation is a disease and the cause of many others; it is entirely incompatible with perfect health or good work in school.

At least one strong article has been written—by a physician—to maintain that women's mode of dress is a sufficient cause of all their physical distress. Undoubtedly it has been responsible for great injury, though present conditions are much improved, so far as tight or long clothing is concerned. We appreciate, however, that women are still handicapped when we see how their ordinary clothing hampers them in gymnastic work. Just at present school girls expose themselves to the cold in a way unsuitable to this climate. Even in winter they go to school bareheaded, in lingerie waists with light undergarments, cotton hose and low shoes. The toughening process is valuable to a certain extent, but such exposure as this means an expensive strain upon vitality. School girls are notably careless of wet clothing and wet feet. Mothers have difficulty in persuading them to overshoes and rain-coats, and teachers find them unwilling to go home when skirts and stockings

are wet through. To sit in wet clothing is dangerous even for an adult woman.

This paper is intended to deal especially with those elements of a girl's life that are detrimental to her health, yet are usually overlooked. It is hardly necessary to include much discussion of the need of sleep. Every one understands that a girl needs about nine hours of sleep in pure air. At present there is a general enthusiasm among young people for outdoor air. If they do not take sufficient sleep it is not because they do not know the need of it.

The recreation of a girl ought to do something toward her recreation, not leave her more exhausted than all her work. But those who have studied the physical development of the girl tell us that the excitement and nervous strain of society and late hours are much more exhausting than hard study for a young girl. This does not mean that she should give all her time to her lessons, only that her amusement be something less wearing than study. She ought to have good times, she is the better for parties if they are limited to reasonable hours and to suitable companions. One element of a high-school girl's life which is seldom mentioned, but is often noted by her teacher, is the detriment that comes to her from social intercourse with those who are a few years older than she, especially with older men. If a girl spends one or two evenings a week in the cultivation of such friendships as these and reads a romantic novel every week it is to slight profit that she spends the rest of her time "over her books." It is pretty nearly impossible for her to concentrate her mind on her work.

It is a very common criticism that there is too much social life in the school itself. It is admitted, at least in this country, that children need some amusements. *If other social distractions could be omitted* what could give a school girl more harmless pleasure than the class dances and parties, under the direction of a teacher-chaperone, parties that include only people of her own age and experience and that close at a proper hour?

A girl's real re-creation is her out-of-door sports and she should receive every encouragement to those that she most enjoys. The implements of such sports—golf-sticks, tennis racquets, boats and skates—are better investments for parents' money than even pretty clothes, if there must be a choice of expenditures. Housework is one of the best possible forms of exercise if done in well-ventilated rooms; it might be profitably taught by mothers under the name of physical culture.

Music study is, I believe, hardly to be classed as a recreation, even though it happens that the pupil enjoys it so much that it does not appear a burden. It is mental work requiring close attention, memory and some eye strain. It makes about the same demands as an extra course in school, and if it seems best for the girl to continue much piano-prictise during the term, she should take five years for her high-

school course. Often a collapse in school that seems inexplicable to the teachers is due to a pupil's adding an hour or two a day of piano-practise to an already full school course. It is worth while for the girl to take music lessons during the summer if she is within reach of piano and teacher; the discipline and regularity are a good thing during these weeks of complete freedom.

Many pupils suffer from eye-strain; every possible care should be taken at home to minimize this, both for the sake of the eyes and for the direct influence upon the mind and temperament. Study before breakfast is very likely to aggravate eye-strain; if there must be early study the pupil should bathe her eyes in cool water and take some food, that the congestion of the eyes may be relieved. A proper light lessens the fatigue of the eyes. By day the student should not face the window and at night her lamp should have an opaque shade. Often the change from a white to a dark-green shade relieves long-continued pain in the eyes.

Reference has been made to a girl's spending time "over her books," and the phrase is sometimes especially accurate. Instructors of college freshmen complain that boys and girls go through preparatory school without having learned how to study. The teachers may be responsible for a part of this, but there are some conditions that the most devoted teacher can not govern. She can regulate a pupil's work in school, but when much of the study must be done at home the home must help in establishing good habits of work. A student needs a well-lighted work-room reasonably free from interruption. It is not necessary that the window have an extended outlook; a girl is likely to establish herself for her afternoon's study where she can get a wide view of the street. With a little attention the daughter of the house may be helped by her surroundings at home to a concentration upon the work at hand that will lessen marvelously the hours that she must spend with her books and give her more time for recreation.

Elements internal and external, elements physical and mental, have been treated together in this discussion and inevitably so, for they are almost indistinguishably interwoven in the life of the girl. How much her health of body depends upon her health of mind no one can venture to say. One feminine characteristic becomes especially evident in the adolescent maiden which has considerable influence upon her health. This is the narrowness of mind that causes her to give undue importance to really minor elements of her life. She comes to believe that there are only two or three things in the world that are really important; if she is an only child she may decide that there is only one. It is undoubtedly desirable that a girl stand well in her class and wear attractive gowns, but there are other things just as essential. When she sees that it is worth while to hold fast to "a taste for simple pleasures" and to promote the happiness of her family and community, and

supremely worth while to make herself an able woman physically, she is well on the way to the attainment of a poise of mind essential to her health and to her breadth of thought. Much of her narrowness may be eliminated by the public school and that very effective education which a child's companions supply. But there are certain chambers of a maiden's mind especially suitable for her mother's furnishing; in the most intimate relations of a girl's life she must naturally find her direction at home.

And is not this the conclusion of the whole matter? Undoubtedly the girl does need "the complementary wisdom of school and home," and sometimes when every precaution is taken at home the school work may be too hard for the girl at some particular time. In this case the parents must lay the matter before the teachers; in some way the work must be lessened, so that a growing girl does not come through each week exhausted. But in most cases it is found that it is not the *work* that exhausts.

The American girl needs the public school. She needs it for its democratic influence, really a powerful element in the mutual understanding between women, which alone can solve the "servant problem"; she needs the acquaintance with boys of her own age which banishes sentimentality; she needs the broadening influence of men-teachers. It does not seem on the whole that there are many points in which the school can do more for the girl than it is doing; it is not in general conditions that she needs more consideration. For it is true that "the teacher has to deal with the average; the parent must accommodate the particular," and that "it is to the parent that the child must look for his (and her) individual protection and care."

In brief, as soon as a girl comes to manifest her difference of sex, she needs especial and intelligent protection at home to free her from strain mental and physical. And when her health and future fulness of life are thus established, they must be guarded by continued oversight of her food and clothing and exercise and recreation and sleep. Her mental and nervous strength must be conserved by guiding her into orderly ways of thought in the personal and intimate matters that obviously do not belong to the public school. When these elements of her life are properly administered at home the American girl can in ordinary cases complete the course of study in the public schools without injury to her health.

The articles to which especial reference has been made are:

"Rest during Menstruation": Dr. Mary Putnam Jacobi.

"The American Girl of To-day": Dr. George J. Engelmann.

Article in *New York World*: Dr. W. Gill Wylie.

"Adolescence": President G. Stanley Hall.

"Effect of High-school Work on Girls during Adolescence": Dr. Helen Kennedy.

SOME ETHICAL ASPECTS OF MENTAL ECONOMY

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TO be economical of one's powers makes for efficiency; to be prodigal, makes for inefficiency. To be efficient in life is the highest ethics. To be inefficient because of prodigality is to be immoral.

It will be observed that in this discussion I follow the Aristotelian conception of ethics as a practical science, rather than as a theoretical science. The object of the discussion is to consider certain modes of mental life, to evaluate them, and to offer a few guiding suggestions for the proper conduct of life.

Professor Paulsen has compared this view of ethics with the science of medicine, which he says, "instructs us to solve the problems of corporeal life, to the end that the body may perform all its functions in a healthy manner during its natural existence; while ethics, basing itself on the knowledge of human nature in general, especially of its spiritual and social side, aims to solve all the problems of life so that it may reach its fullest, most beautiful and most perfect development. We might, therefore," he concludes, "call ethics universal dietetics, to which medicine, and all the other technologies, like pedagogy, politics, etc., are related as special parts, or as auxiliary sciences." ("A System of Ethics," p. 2.) The purpose of ethics, then, is "to determine the end of life, or the highest good, and to point out the way or the means of realizing it."

This much by way of definition is given preliminary to my discussion of mental economy as a phase of ethics, in order to justify my treatment when I seem to digress from the immediate consideration of right and wrong and to discuss questions which might properly be also catalogued under pedagogy or mental hygiene.

All will agree that no life is most nobly lived unless it has secured the complete unfoldment of the richest inheritances bequeathed by ancestry; unless it has appropriated environment in such a way as to secure the limits of individual advancement; unless it has rendered the utmost possible service to society. To fail in these particulars is to be prodigal and uneconomical. To be uneconomical is to be unethical. The world is full of work to be done, problems to be solved, which are of proportions never before assumed. To meet these duties and responsibilities requires the highest products of intellectual evolution, keen and broad sympathies, and vigorous, sustained will-impulses.

To live completely and ethically, every one should accomplish more

than his parents. This means not only that he should secure more tangible results, but that he should develop and expend more force than his ancestors. Each one stands on the shoulders of the past and may utilize all the accumulations of the past. In order to accomplish more than our forefathers, it is absolutely necessary, however, to husband our forces. But with the increase of potentialities, we must also reckon with the fact of the manifold additional ways inviting and exciting to depletion of powers. As an illustration, let us note the excessive stimulation to which the eye is subjected. In our present civilization we have come to depend more and more upon vision. The strain upon the eye in gaining knowledge of the objective realities about us has been increased a thousandfold by modern modes of travel. In addition, we must use the eye to interpret language symbols about myriads of things inaccessible to personal inspection. Primitive man had only a narrow range of things to see, and those usually at some distance. Hence he knew not of eye strain resulting from the microscopic scrutiny of a vast kaleidoscopic scene. Formerly man could deliberate in seeing the few things within his range. But now he becomes a globe-trotter, compacting into a few weeks the view of scores of nations, vast expanses of country, the collections of ages, and the unceasing activities of the heterogeneous throng.

In a week's jaunt and doing a world's fair, present-day man sees more and hears more, than was possible in a whole lifetime, a century ago. Besides these activities the eye is made to do duty in reading the twenty-four-page daily, the forty-eight-page Sunday edition, in scanning a half-dozen weeklies, going through a cartload of magazines, to say nothing of all the latest books which one is supposed to read.

The ear is equally assailed with the ceaseless hum of voices, door bells, telephone calls, whirl of the trolley, the shriek and clang of the locomotive, the maddening grind of the sleeping car or the twin-screw steamer (upon which we take our vacation rest!), the deafening roar of the factory, the clatter of galloping hoofs and rattle of wheels over paved streets. Even at night we must be assailed, business must not stand still, goods must be sent by return mail, limited trains must outdo lightning specials. Even on Sundays we are not permitted to listen to restful sermons—they must be such as to give rise to glaring head-lines, and the music is often of ear-splitting pitch.

The first and foremost great law of mental dietetics that should be impressed early and often is that one long ago stated by Juvenal, viz, *mens sana in corpore sano*. Every parent and every teacher should understand that the first business of the child is to become a good animal; childhood years should be largely vegetative. His primal inheritance is physical. To have big lungs, firm muscles, elastic step, ruddy cheeks and scintillating, unspectacled eyes, and every sense alert, at the close of youth are priceless possessions with which a knowledge

of algebraic formulæ and a few dates in history are not to be compared. For what shall it profit a man if he gain the whole world of knowledge and have not physical power to use it?

Not only is a sound body an absolutely necessary correlate of a sound mind, but mental processes themselves are incomplete without muscular accompaniments. How vague would be our ideas of walking, talking, writing, painting, molding and chiseling without the muscular accompaniments. You can not even think hard of a word without involuntarily moving the muscles. Try it sometime by opening the mouth and thinking the word bobbin, bubble, etc. So-called 'mind reading,' table turning, the planchette, all illustrate the same fact.

Again, the body possesses all the gateways to the soul through which all knowledge of the outside world must come. Close the eyes, stop the ears, and deaden all the other sense-organs and the child is mindless—an idiot. Finally, no message can issue from the mind, nothing of its workings can be revealed and no control of the world forces be secured, save through the medium of physical organs—the muscles.

Consequently, to secure the highest mental efficiency we must give due consideration to bodily culture. Any education which disregards this is a failure. Every student should have sufficient food, adequate sleep, proper exercise, abundant recreation and in every way seek to promote bodily vigor.

The Socratic doctrine of innate ideas has been responsible for many pedagogical sins. Socrates taught that the business of teaching was to draw out these inborn ideas. The middle-age ascetics went so far as to assert that spiritual development could be best furthered by bodily torture. Consequently, in order to elevate the mind they strove to devise tortures to crucify the flesh. We read of their fasting, eating inappropriate foods, going barefooted and otherwise scantily clad in the dead of winter, wearing hair shirts with the hair inside; bathing in ice-cold springs in winter, sitting on sharp nails, assuming unnatural and extremely uncomfortable postures for months at a time, binding the body with ligatures, loading the body with weights, living in filth, going without sleep and working all day and all night, etc. Simeon Stylites is said to have lived for forty years chained on the top of a high pillar and Macarius slept for months in a marsh, exposing his naked body to the stings of venomous flies, in the misguided notion that the greater the bodily penance the more exalted the spirit became. In fact they tried to devise every possible means of excruciating torture of body in the attempt to exalt mind. To this pernicious doctrine of the relation between body and mind can be traced much of the long intellectual night of the middle ages. To it are directly traceable the beliefs in witchcraft, demonophobia, sorcery and the

superstition that insane people were possessed of evil spirits. Professor Monroe ("History of Education," p. 248) says, "the virtue of the monk was often measured by his ingenuity in devising new and fantastic methods of mortifying the flesh—all these forms of discipline were for the sake of spiritual growth, the moral betterment of the penitent: all these, as the very significance of the word asceticism indicates, reveal the dominant conception of education which prevailed throughout this long period,—the idea of discipline of the physical nature for the sake of growth in moral and spiritual power." So long as the body was considered gross and evil and a mean tenement of clay from which the spirit should strive as soon as possible to escape, it was but natural that bodily care, and much less culture, should be considered unworthy objects of education.

Sleep as a factor in student life does not receive adequate consideration from many students. The student who does not take regular and sufficient sleep is pilfering his own bank account. There is absolutely no substitute for it, and when once lost, restitution can not be made even by a nap in the class-room. Nervous tissues exhausted by a day's activities can only be restored by sleep. Dr. Hall says that no child should be allowed to go to school without having had nine hours of sleep and a good breakfast. This would not be a bad rule to guide student life. Parties, athletic jaunts, examination crams, and even working for one's living, which cause students to remain awake beyond the midnight hour, transgress all laws of mental and physical hygiene. There is doubtless no cause so frequently producing nervous breakdown as loss of sleep. Several former students who were pale and anemic while here have returned after a hard year's teaching experience with ruddy complexion, increased weight and all the appearances of vigorous health. I have inquired concerning the change and have been answered, "I guess it is because I get enough sleep now."

The student who goes to college to become a hermit, not touching elbows with his college mates and developing no interests through hearing music, attending lectures on varied subjects, seeing nothing of the great busy world about him, misses a vital factor of college life. His procedure is uneconomical and therefore unethical, for when he emerges from the college halls into the busy, bustling world, he will find himself behind the procession. Because he has not seen the larger world while acquiring his book knowledge, he perceives no relation and often feels that the world is somehow out of joint because it does not conform to his bookish ways. To become efficient he must begin again and study the world about him. He must gain its view-point, adjust himself to it; he must now try to gain friendships which should have been established in college. All this is a wasteful, selfish process.

On the other hand, some students need to be cautioned when they make the opposite and equally grave error of saying that "My asso-

ciates teach me more than my books and class work." Possibly they do, but it is not the fault of the books nor of the classes, nor any compliment to the associates. He says, "I study men, not books." This is sound, if rightly interpreted, but he should know that there are some men besides freshmen well worth knowing. Some of them can only be known by going to their books. He should learn to study individuals as well as masses, the world's teachers as well as his own classmates; he should look up as well as around. The college course is certainly a failure if it has not given the student lasting acquaintanceships with a few superior students, some great men on its faculties, and many of the world's intellectual élite, who can only be known through the pages of history and the great literatures of all ages. Great ideals which become guiding stars of one's destiny should be clearly glimpsed. The great laws of science should have banished superstition forever from his mind and given him a new interpretation of universal development and history. Finally a clear conception of philosophical principles should act as a great balance wheel enabling him to interpret life and all its manifold activities. It is through books and master minds that the student should get meaning for all his varied observations and activities. To regard books and class work as inferior and something to be endured is to miss the whole point of a college education. Colleges are founded and maintained for the specific purpose of furnishing books and teachers, and all class work, once selected, should have the right of way. Student programs should not be so overloaded but that all the accessories may be duly emphasized. Recreation as well as work should become a part of one's religion. The gospel of relaxation needs evangelists as well as the gospel of work.

It is important for the student to understand early the force and value of habit. Much time is lost by every one of us because our early training did not render automatic all those activities that we have to perform constantly and in the same way. Purely mechanical work can be controlled more economically by lower nervous centers than by higher. In childhood and youth the nervous system is plastic, a prime condition for memorizing and fixing habits. Among the habits that should become ingrained during this period are those of correct bodily postures and activities, correct speech, the multiplication table, spelling, writing, those involved in learning to speak foreign languages, etc. Most habits are controlled by the spinal cord, which is early developed. Hence we should form habits early, so that the brain may be relieved later of mechanical work and be concerned with higher operations. As Dr. Balliet has observed, "At first a child uses his brain in walking, later he can walk from habit and walks therefore with his spinal cord. As first we spell with painful consciousness, later we spell familiar words of our vocabulary with little

or no consciousness. Children ought to be trained to write and spell mainly with the spinal cord, and use all their brain power in thinking the thoughts to be expressed. We do many things with the spinal cord to relieve the brain. We walk with the spinal cord, we write and spell with the cord; I suppose we knit and gossip with the spinal cord; indeed we may sing and pray, not with our hearts, nor with our brains, but with the upper part of our spinal cords. We tip our hats to each other, not with our brains, but mainly with our spinal cords; when we meet people whom we do not wish to see, we often shake hands mechanically with our spinal cords—hence we speak of a ‘cordial welcome.’”

Not only do these elementary physical activities become automatic, but also processes of judging and reasoning must become largely mechanical before becoming serviceable. One’s thinking is largely specialized and judgment outside of the well-beaten track of thinking is not very valuable. The lawyer’s opinion concerning disease is slowly formed and unreliable; the doctor’s judgment about legal matters likewise is valueless. The expert in a given line is one who has studied widely and who can form instantaneous judgments because of the habitual consideration of the data. Difficult studies pursued through a long time until mastery is complete become as simple as the alphabet. Mathematicians become so familiar with the calculus that they read it for recreation when fatigued with other work. The lawyer can instantly cite scores of cases and precedents for which the tyro would have required hours to summon to the foreground of consciousness. Hence, when knowledge is to become usable it must be pondered long and every detail absolutely appropriated. To arrange work in such a way as to sustain interest through variety and at the same time dwell upon it until thoroughly comprehended and appropriated is high teaching art. The demands for variety frequently allure to new fields before assimilation has been effected.

Even the will is much more a matter of habit than we usually think. It is too often regarded as a sort of psychological ghost which pursues us about, compelling us to do certain things and prohibiting us from doing certain other things. Every one is supposed by the popular mind to have at birth a will of unchangeable quality and quantity. This is absolutely incorrect. The child has impulses but is practically will-less. His will must grow and develop like any other powers. We use the will when we perform actions which we control. When we lack control, either muscular or mental, we lack will, or possess a diseased will. When a child can pick up a pin, thread a needle, tie a knot, walk without tottering, run, talk plainly, etc., he manifests definite mental and muscular control and therefore manifests voluntary power.

Now these activities were only possible after long practise and the development of definite habits of activity. As Dr. Royce says, “Our

minds become full of impulses, of tendencies to action, of passions, and of concerns for what we take to be our welfare. All these impulses or concerns get woven by the laws of habit into systems of ruling motives which express themselves in our regular fashions of conduct. The whole of our inner life viewed in this aspect appears as the purposive side of our consciousness, or as the will, in the wider sense." We even need to put new interpretation upon the meaning of the freedom of will. Freedom means power of choice, power of desire, but not necessarily power of execution. The life-long habits of every individual chain him down to certain types of action and it often takes long practise to break up fixed customs and habits of activities. This has its sad side and also its advantageous side. Were it not that we willed with all previous acts of willing, and were it not true that all our habits hold us to certain types of action, it would be impossible to predict what the individual might do on a given occasion. When we analyze the meaning of character, we find that it implies nothing more or less than the accumulated tendencies toward action in particular directions. The man who has habitually acted in a righteous direction has built up tendencies toward righteousness. On the other hand, one who has sown a generous supply of wild oats in youth is sure to reap in old age an abundant harvest of viciousness. It could not be otherwise. We are enjoined in the Scriptures that 'whatsoever a man soweth, that shall he also reap.' A prose-poet has stated that "we sow a thought and reap an act; we sow an act and reap a habit; sow a habit and reap a character; sow a character and reap a destiny." Professor Fullerton says that the old interpretation of absolute freedom would make this a melancholy world. In such a world of freedom no man could count upon himself and no man could persuade his neighbor.

We should be powerless to lead one another into evil, but we should be also powerless to influence one another for good. It would be a lawless world with each man cut off from the great whole and given a lawless little world all to himself. He said, "To-morrow I am to face nearly one hundred students in logic. It is a new class. I know little about its members, save that they are students. I have assumed that they will act as students usually do and that I shall escape with my life. If they are endowed with free will in the old interpretation, what might I expect? What does free will care for the terror of the dean's office, the long green table, and the committee of discipline? Is it disinterested in logic and does it have a personal respect for me? The picture is a harrowing one and I drop the curtain upon it."

Hence, from a pedagogical point of view, how important to fortify the child by habits against that which is undesirable in conduct by developing in him impulses and tendencies through experience in right conduct. Right conduct in children there must be if we expect right conduct in adult years. The man who has to reflect to keep his hands

from his neighbor's pocket does not possess honesty of a very high type. It is only the one who possesses no impulse to pick his neighbor's pocket and who does possess an instinct of abhorrence against such an act that is really honest. The one who is tempted evinces disease of will.

Independence of thinking is a rare but thoroughly economical mode of activity. Many people are so unused to thinking for themselves that they would be frightened at the appearance in consciousness of a thought really their own. It has been said that "animals think not at all and some men a little." Most of the thinking of the world is carried on by a few individuals. The rest of the world are mere echoists. This is a terribly wasteful process, and sinful. If more people were independent thinkers there would not be a yearly output of millions of barrels of patent medicines, the main ingredients of which are alcoholic preservatives. Soothing syrups with opiates are fed to children because they are said to cry for them. The children are quieted, oftentimes so effectually as to be stupid through life. "Harmless vegetable remedies" is a magical phrase. Perhaps this is why so many take extract of hops and barley, spirits of corn, nicotine and opium!

Because of lack of independence of thought, superstitions have always hindered the world's progress. Even to-day the number 13 is so ominous that you can not get a room number 13 at a hotel, can scarcely have 13 at table. Friday is still considered so unlucky that steamship companies hesitate to make sailing dates on Friday. Farmers still plant their potatoes in the moon, and men carry potatoes in their pockets to cure rheumatism. Only a few days ago I saw a man in this city who had a rattlesnake's tail in his hatband to ward off rheumatism. Clairvoyants and fortune-tellers apparently find plenty of dupes, if we are to judge by the wealth of their advertising. Thus on every hand we find ample evidence that people are sinning and being sinned against simply because of slothfulness in thinking.

In ancient times and in the middle ages the scholars shut themselves away from the world, quiet as it was, in order to avoid the distractions against thinking. While they erred in not recognizing that the senses are the source of all knowledge, were they not wise in recognizing that to think effectively demands solitude?

I wonder if there is not much in modern student life that militates against the deepest thinking. With the multiplication of student activities, of themselves in no way secondary to any others in importance, have not the opportunities for sequestered contemplation decreased? With football, baseball, basketball, tennis, rowing, skating, the literary society, the dramatic club, the freshman banquet, the sophomore cotillion, the junior prom, the senior hop, numberless fraternity, sorority, and various other house parties, the various church,

social and other engagements, besides the loafing hour, the theater, concert, special lectures galore, the newspapers and magazines to scan, the letters to write home and other places, applications for schools to make, etc., one might well exclaim, "And when do they find time to study?"

Many students take on altogether too many activities. In my own observation I have known several students who arrested their development badly by getting too many irons in the fire. A student's popularity is not infrequently the cause of his intellectual arrest. By attempting debates, athletics, dramatics, study and society, all at the same time, his energies are dissipated, his growth stunted, while his plodding companion by everlastingly keeping at a few things finally becomes a master and frequently astonishes even himself as well as his acquaintances. Even short courses with too much variety, except for inspiration, are uneconomical, because they do not lay permanent foundations. Too many open lecture courses provided by faculties may easily be distracting and a source of dissipation. The student must learn to say no to the siren's voice which continually beckons him on to new fields.

I sometimes feel that there ought to be some course labeled "thinking" in which the individual should be isolated from everybody long enough to really empty his mind of all ideas which are merely echoes, and then to discern what are really his own. With all the distraction of congested social life, the time may come when it would be a blessing for the state to imprison a few great men each year and allow them only pen, ink and paper. It may have been a fortunate thing for the world that John Bunyan languished in prison until his thoughts had had time to germinate and come to full fruition. Possibly the blind Milton, shut away from the distractions of visual stimuli, may have looked within and discovered thoughts struggling for expression, but stifled with ephemeral ideas of sense perception.

While we are rightly emphasizing group activities as an aid in developing altruism, I wonder whether students do not sometimes misinterpret its meaning. Self-activity is fundamental in the process of acquisition of knowledge. No knowledge is of much value that is not made one's own personal possession. This means more than the recital of words and formulæ gained from books and companions. In their desire to be helpful I sometimes see students in groups, even sitting on the stairways when the crowds are passing, believing they are *studying* together. When one hears the bits of gossip interspersed between the formulæ, the declensions and historical dates one wonders where the calm reflection, deep concentration, analysis, comparison, doubt, contemplation, deliberation, complete abstraction, enter in.

An oversocial room-mate who persists in retailing the gossip of the day during the hour set apart for study is an uneconomical acquisition.

Psychology has thoroughly demonstrated that we can consciously attend economically to only one set of ideas at a time. Even much note taking in class is an uneconomical distraction. The faithful but misguided student frequently attempts to take down every word uttered. He deceives himself, for what he hopes to carry under his arm he should have in his head. No wonder that sometimes the less scrupulous one who cuts classes and borrows notes instead of writing them fares about as well.

In student life it is important to thoroughly master a task as speedily as possible. To skim over a lesson and leave it without mastery is wasteful. The process may be repeated a dozen times in this way and then be only half learned. Hence, "whatsoever thou findest to do, do it with all thy mind and with all thy heart and with all thy strength." In mastering things for keeps two attitudes are necessary—interest and attention. Attention is the mother of memory; interest is the mother of attention. Hence, if you would secure memory, you must capture the mother and the grandmother. It is the business of us all to be interested in what we do, and it is unethical to regard our work as drudgery. I sometimes say to students, you never will be great successes as teachers until your work has come to occupy all your waking moments and even your hours of sleep. It must be your life. If you wish to know what you are interested in just catch yourselves suddenly occasionally, when you have no prescribed task, to see what you are thinking about. Those great dominating, insistent ideas indicate your real interests.

May I say a word on the ethics of cramming for examinations? The method is a delusion and a snare. Ideas are not grasped, associations are not made, brain tracks are not made permanent, and even though the student might pass an examination on such possessions, like the notes of an insolvent bank they are found to be worthless trash when put to real use. Instead of wisdom more to be prized than fine gold, such a process may leave one with only bogus certificates. Make your mental acquisitions absolutely your own while going over the subject day by day, take ten hours of sleep before every examination day, and the results need not be feared. In trying to make possessions most permanent and most economically I give frequently the following recipe: Study your lesson as if you expected to teach it. When you can teach it to some one else you possess it. Frequently actually try to teach your lesson. If your room-mate will not submit, inflict it upon an imaginary pupil. Some one said, "I do not lecture to instruct others, but to clear up my own ideas."

Although young shoulders should not become bowed down by an overweening sense of responsibility, yet it is sinful not to impress the young with the importance of the morning of life. The old adage

that it is never too late to mend should be replaced by the one that it is ever too late to become what one might have been, if an opportunity has been allowed to slip.

Students should early recognize the importance of making the most of the morning of life. Biologists have come to recognize the economic value of the period of infancy. The period of infancy is the period of plasticity, the period when the individual can be molded and modified; in other words, educated. The longer the period of infancy, the higher the degree of educability. The newly-hatched chick has a short period of infancy. On emerging from the egg, it can perform almost all the activities which it will ever be able to perform. It has very little to learn, very little possibility of learning and very little time in which to learn. The young dog has more to learn, a longer period in which to learn it and larger possibilities of acquiring new activities. The human being has the longest period of infancy. By infancy I do not mean alone the period when the child is in the cradle. Biologically it includes all the period of life from birth to maturity. It is the period of plasticity, the period of educability. After this period, the possibilities of education grow less and less. Perchance there are freshmen who may peruse this. I desire to give you a few words of comfort. You may be frequently derided by the learned sophomores who call you "greenies" or "freshies." Take comfort and regard the appellation "freshmen" as a mark of honor rather than derision. To be fresh or to be green means that you are still growing. All should wish to be green and to grow as long as possible. May you live to a green old age. Even the sophomores are all right. Woodrow Wilson said, "A sophomore is one in whom the sap is rising but it has not yet reached his head. He will eventually mature."

Professor James says that one seldom gets an entirely new idea into his head after thirty. After that period one may erect a splendid structure upon the foundation already laid. But if any subsequent structure is to be reared the proper foundation must have been laid before that time. For "outside of their own business," says James, "the ideas gained by men before they are twenty-five are practically the only ideas they shall have in all their lives." We can not get anything new, for disinterested curiosity is past, instincts have died out, bonds of association have become fixed, "mental grooves and channels set, the power of assimilation gone." Hardly even is a foreign language learned after twenty spoken without a foreign accent. "In most of us, by the age of thirty, the character has set like plaster, and will never soften again." The most possible should be made of early life, for, although it is a fact that the number of cells in a given brain is complete at birth, yet mental exercise must determine the number that becomes fully developed. Moreover, the period for development lies largely between birth and maturity. It is the period when nerve

matter is plastic and when growth and replacement exceed disintegration.

Brain workers do their best between the ages of twenty-five and forty-five before that they are preparing for work, after that their work, no matter how extensive, is largely routine. Lawyers and physicians do much of their practise after forty, but the learning was accomplished before forty or forty-five. Successful merchants lay the foundations for wealth and success in youth and middle life. The great men that we know are all old men; but the foundations for their greatness were laid when they were young. Philosophers have founded and announced their systems in youth and early manhood; divines and religious teachers have originated their creeds and have been most effective as preachers in early manhood.

Statesmen have projected their greatest acts of legislation, diplomacy and reform in early life. In the morning of life scientists have wrought out their data and practically formulated their theories; generals and admirals have gained their greatest victories; lawyers have paved the way for leadership at the bar, physicians have laid the groundwork for their greatest discoveries, poets and artists and musicians have planned and in many instances executed their greatest masterpieces.

You, young men and women of the colleges and high schools, are picked individuals. A process of selection and sifting going on for many years in your own lives, and for generations in your ancestors, determined who should go to college. The state endows its universities to enable its intellectual élite to secure the development which their native worth makes possible. The function of the school and the university is not to create brains, but to mature them. The school is like a problem in multiplication in which the student is the multiplicand and the institution the multiplier, and, as in mathematics, if we have significant figures for our multiplicand the result is significant, but if we have ciphers for the multiplicand the result must be zero.

Your efficiency in life depends largely upon your physical and mental health and your habits of work, rest and recreation. To conserve your inborn potentialities and to multiply your talents is not only a high privilege but your greatest immediate duty. To fail is to be morally culpable, to succeed betokens true wisdom and virtue. No worthier object of contemplation can occupy your mind than the Socratic admonition, "Know thyself."

THE CHINAMAN AND THE FOREIGN DEVILS

BY CHARLES BRADFORD HUDSON

DETROIT, MICHIGAN

THE ancient examination halls at Peking have been transformed into a military school. To the western mind there is nothing startling in the item, nor significance beyond the fact that it suggests that China is at last rousing from her centuries of complacent introspection and retrospection, and purposes to learn something which the rest of the world has found useful. A mere change in the curriculum of certain Chinese students, it would seem, of less interest to mankind in general than if Oxford should suddenly abandon the study of divinity or the humanities. But to the Chinaman it means more. It is a change of greater moment, more revolutionary than would be the overthrow of the Manchu Dynasty. Indeed, a dynastic change would be comparatively an insignificant and commonplace event. In the fourteen hundred years since the course of studies was prescribed by which the Chinese student fits himself to enter the aristocratic order of the literati, and thereby to become eligible to government office, the celestial empire has undergone a full score of revolutions, each one of which has resulted in the establishment of a new royal line. But during that period, which has witnessed the birth, decadence and death of christian empires, the requirements of Chinese scholarship have been unchanged. Until to-day, the student who presented himself at the triennial examination at Peking as a candidate for the highest degree attainable, the 'Chin Shi,' or 'Enrolled Scholar,' has been questioned on precisely the same subjects, tested by the same literary standard in his essays, as his predecessor of the sixth century; and has prepared himself for the ordeal by the study of classics that were hoary before the christian era began. The change has come. Philosophy must yield a place to the art of war. Its import to China, the most ancient, the most conservative, the most peace-loving nation on earth, is beyond our power to estimate. Its portent to the world at large is hardly to be conceived; to be conjectured, however, on a review of some of the features of the rough schooling by which this placid people has been educated to its needs.

It is many years since the powers began prodding the Yellow Dragon, with bayonets and otherwise, in the determination to awaken him from his lethargy; but it is only of late that they have begun to ask, with a faint quaver of trepidation, 'Suppose he should rouse . . .

what then?' The question has even provoked some slight symptoms of hysteria, expressed here and there, when the monster has shown signs of life in response to the systematic and persistent annoyance, in shrill clamors about the 'Yellow Peril,' with chilly sensations at the recollection of the hordes of Jenghiz Khan. The cry has been taken up, echoed, and having served its purpose as an interesting bogie for the newspaper-reading public, has been scoffed down; but there has remained more or less speculation, not unaccompanied by misgivings, as to whether the dragon had not been better left asleep. The fact has been taken into consideration rather abruptly and quite seriously that he represents 400,000,000 people, capable of truculent forms of vengeance on occasion, and animated by a national feeling of a definite and positive kind. These reflections might properly be productive of uneasiness did we not reassure ourselves with the self-satisfying assumption of the mental, moral and physical superiority of the Indo-European race, and the conviction that it is our destiny to inherit the earth. We indulge in a comparison of ourselves with the Mongolian in a way which leaves him relatively far down in the human scale, and have taken it for granted, hastily perhaps, that he can not rise. Experience has shown in the past that he was averse to fighting, and that he could be expected to submit, with no resistance much more forceful than a protest, to whatever imposition or exaction any bullying occidental nation might see fit to make. As a consequence, the dealings of the christian nations with China have constituted a long series of outrages upon that country and of offenses to decency, at the catalogue of which it is difficult to say whether one should be more astounded at the Chinaman's endurance, or humiliated by the shamelessness of the white man's oppression. We have fairly won our title of "foreign devils." We bear it with composure, with a good-humored scorn or, at most, with a mild resentment that the Chinaman can be so unreasonable as to give us the designation. But however we accept the term it is quite certain that he applies it with earnest sincerity, and that it is an expression of a hatred and contempt for the foreigner almost universal throughout the empire.

There has been evidence enough of this hostility to make it seem worth the while to inquire what its basis may be, but the question is seldom raised. When raised it is usually answered by a vague reference to the Chinaman's "ignorance," to his fanatic antipathy to christianity, his opposition to progress or his national egotism. To the first of these it may be rejoined that he is not ignorant, in the sense, at least, of being unlettered or unintelligent; for in no other country in the world is learning more wide-spread or more highly honored, no country has a greater literature, and few races are distinguished by keener intellect than the Chinese. Their learning is not ours, and judged by our standards their educational system is absurd; but it is

the one avenue to political preferment or social eminence, and no village is too small or obscure to have its school, no boy too humble to be eligible to its advantages. If their studies are confined to the ancient classics, as were those of the European scholar not many generations ago, the defect is in part compensated by the absolute thoroughness required to enable a candidate to pass the examinations; and whatever the practical value of the learning, the mental discipline is of the most severe. It has produced a race of students; has developed an intellectual capacity which, when a young Chinaman enters a western university, makes him the peer of the best of his white fellows.

It is true that the Chinese are ignorant of the outside world and its arts, and their ignorance is only surpassed by their indifference; but their hostility to them is not traditional. In medieval times there was a considerable and friendly intercourse with the nations of the west, and christian envoys, priests and traders were welcomed, with whatever knowledge or commodities they could bring. From the seventh to the tenth century the Nestorian Church made many converts, and later the Dominican and Franciscan Orders established missions without opposition. In the fourteenth century Catholic churches were so numerous that the Papal See made China an archbishopric under John of Monte Corvino. For that remote period commerce with Europe was important, and flourished until overland communication was cut off by the rise of Islam, leaving China for two hundred years forgotten of the world.

The attitude of the Chinese toward systems of faith other than their own has never been one of antagonism. In the first century an envoy sent out by the emperor to bring back the religion of the west returned with Buddhism, which was accepted as superior to the indigenous form of belief, and has now a more numerous following than either Taoism or the philosophy of Confucius. Twelve hundred years later the Venetian travelers, the Polos, were sent as emissaries from Kublai Khan to the Pope with the request for instructors in christianity. So far as religious belief is concerned the Chinaman is as tolerant today as he was then. He has no enmity for christianity *per se*, and objects to it only because he fancies its purpose and effect are to alienate the Chinese convert—to make him, in his sympathies, a “foreign devil.” This suspicion is sufficient to rouse his hostility and provoke his violence. He hates the christian because he is a foreigner; not the foreigner because he is a christian. He is far too well-balanced and temperate to be a religious fanatic, and is possibly more liberal in his views of questions of faith and worship than are we. Taoism, the boundaries of the empire, side by side with the agnosticism and atheism of the Confucianists, and there is no record of religious wars or persecution, no history of an inquisition, no massacre of St. Bartholomew, no ostracisms because of faith or the want of it. The

Chinaman believes with moderation, and the gods he has bear lightly upon him. The coolie propitiates his Joss, but when the wooden god fails to respond in a satisfactory manner the devotee does not scruple to maltreat him. Recently the great viceroy, Yuan Shih Kai, ordered certain temples in Taotingfu to be cleared of their idols to make room for police stations, and the images were thrown into the river. To the worshipers it was a joke on the gods. "They are having their first bath!" said one, and the crowd laughed with sacrilegious glee. This is not the stuff of which the religious fanatic is made.

The opinion that the hatred of the foreigners arises from opposition to progress is based upon better grounds. The Chinaman has opposed it, has resisted it with an inertia as of the everlasting hills, but from his point of view he has been justified. One phase of western progress is the development and use of labor-saving appliances; but the introduction of such machinery into a Chinese community means calamity. Their economic conditions are adjusted with delicacy so great that it is only by incessant toil that the laborer can earn enough to keep himself and his family from starvation, and the foreign contrivance which will accomplish fifty men's work in one day may entail famine upon forty-nine and their dependants. From their standpoint the argument against machinery is forcible. We have excluded the Chinese coolie from this country merely because he is able to do more work and better work, and is willing to do it for less pay, than our white laborers, though the danger of starvation to the class with which the Chinese workman competed was not immediate, but extremely remote. There seems to be a suggestion in this that possibly the Chinaman is entitled to object, on his part, to the presence of the foreigner and his machinery. His right to the recognition of his objection is, of course, not to be considered by any power, because he is not yet strong enough to enforce it. There are indications that some day he may be.

But even the question of domestic policy does not suffice to account for the intense hostility which the alien has met everywhere in China, manifested in repeated uprisings and the infuriate cruelty of mobs, and which is too universal and obstinate to be attributable to mere prejudice. The Chinaman is wholly rational—rational enough to perceive, after due deliberation, the benefits to accrue from the adoption of those products of western inventiveness which do not threaten his livelihood, as may be inferred from the existence of modern arsenals in full operation, from the rapidity with which railroad and telegraphic communication is being established throughout the realm, and from the evident purpose to learn more of the arts, peaceful and other, which have been developed in Europe and America. It is to be assumed that a people gifted with much good sense and a sobriety of mind beyond the ordinary will not cherish a race-hatred so deep-seated, persistent and uncompromising without good and ample reason. The reason in this

instance is not far to seek. Simply stated, it lies in the circumstance that they have found in their intercourse with white men that the white man is a scoundrel. Other races have learned the same lesson through experience disastrous just in proportion to the value of their territory or property in the eyes of the rapacious Caucasian, and that China has thus far escaped complete dismemberment is due solely to the mutual jealousy of the powers which have long had that ambition and design. Her losses of domain have not been great, but she has been made to suffer, nevertheless, as no other civilized nation since the wreck of the empire of the Incas by Spain. Her first contact with Europeans in modern times began early in the sixteenth century, and from the beginning it was of a nature to fully warrant the sentiment with which she still regards them. Successively, the French, Portuguese, Spaniards and Dutch descended upon her coasts, ravaged and destroyed towns, and massacred their inhabitants. The Portuguese captured Ningpo, and held it until the populace, enraged by their acts of cruelty and oppression, rose and drove them out with heavy loss of men and ships. Later, they seized and fortified the peninsula of Macao, and after repeated efforts to expel them the Chinese government granted the privilege of occupation, conditional upon the payment of 500 taels annual ground-rent. In the treaty it was specifically stipulated that China should retain sovereignty over the territory. This treaty, however, was so manipulated by the Portuguese translator that according to the text of the copy which went to Lisbon all rights over Macao were ceded to Portugal, China being allowed merely to maintain a consulate. When at length the fraud became known at Peking the imperial government protested, but was forced, in order to avoid a war with the invader, to formally cede the peninsula, which remains Portuguese territory. The Crown of Portugal draws a small revenue from farming out the right to operate establishments for playing fan-tan, a game prohibited by the laws of China.

In 1854 Macao became the seat of the infamous coolie traffic, which for a quarter of a century paled the worst horrors of African slavery. This trade was originated by the English to supply cheap labor to the colonists of British Guiana. In the early years of the enterprise the coolies were induced to emigrate on legitimate contract for seven years' service at the rate of something over four dollars a month, with food, clothing and shelter provided by the planters. After the independence of Peru she entered the traffic to secure workmen for her mines and for the guano pits of the Chincha Islands, and Cuba followed her example to provide for her plantations. As the demand for the coolies increased the means employed in procuring them became more and more unscrupulous. Labor agents infested the Chinese ports, the natives were decoyed by fraudulent representations, systematic kidnapping was inaugurated, armed junks were employed to raid the coasts for captives,

and prisoners were purchased outright from the leaders of factions engaged in internecine wars. Depots were established at Macao where the victims were herded under heavy guard until sufficient numbers were obtained for a cargo, when they were crowded into transports and shipped under conditions of misery, filth and brutality which surpassed in atrocity those of the "middle passage." Arriving at their destination, they were sold like cattle to the highest bidders, to enter a servitude which differed from slavery only in being for a limited period, and in the fact that their masters, having no interest in them as property of value, were concerned only to work them under the lash to the extent of their endurance. Those were fortunate whose fate did not land them in the Chinha Islands. Here they were forced to toil under treatment so inhuman that of the four thousand wretches imported from the beginning of the traffic until 1860 not one survived. Those who did not die from the effects of cruelty and exhaustion committed suicide.

The efforts of China to induce the powers to suppress the trade were of course unavailing. There was money in it. But when at length the scandal became intolerable some perfunctory measures were taken by those nations not financially interested, to end, or at least to modify, the worst of its features, and in about ten years they succeeded in making regulations, in concert with the Chinese government, which rendered it unprofitable. But China had gained additional experience of the "foreign devils."

It would be unfair to Portugal to cite her case alone. She is not unique, and far from conspicuous, among those who have proceeded on the assumption that China has no rights which any able-bodied nation is bound to respect. There has been a want of harmony in other matters, but not in this. The helplessness of their victim has made the same appeal to all, and they have responded in a course of brow-beating and bleeding with a unanimity of impulse that is astonishing. The respectable Dutch were early in the game. In 1622, under no pretext of war, nor with better excuse than might ease the conscience of a pirate, they seized the Pescadore Islands, impressed the native inhabitants at the point of the bayonet and compelled them to build fortifications. From this stronghold they ravaged the coast and the Island of Formosa, pillaging and slaying, but, finding it unremunerative, finally wearied and withdrew. The French were less direct in their aggressions and began their spoliation, not in China proper, but in the Kingdom of Annam, where a party of adventurers had gained a foothold in the latter part of the eighteenth century by aiding in the restoration of the deposed Annamese king, Gia Long. In 1859 the murder of a number of missionaries led to the invasion of Annam by the French and the seizure of several provinces. Later, the existence of mineral wealth in Tongking, an ancient dependency of China, was reported by French

explorers, and it was at once found necessary to despatch an expedition into that country for the ostensible purpose of suppressing disorders caused by bands of disorganized followers of the Tai-ping rebels. During the operations of the expeditionary force it came into collision with the Chinese troops by which some of the towns were partly garrisoned, and at the end of the war France found the circumstance to be worth \$15,000,000, which she compelled China to pay, in addition to the cession of Tongking, which is now a French province. But in 1882, before the hostilities had begun, and while the French minister was at Peking negotiating a settlement of matters connected with Tongking, certain French warships quietly dropped anchor in the harbor of Foochow. Their coming had no appearance of menace, and the Chinese were without suspicion that the visit was otherwise than friendly. The fleet lay for several weeks, and its officers had exchanged the usual courtesies with the authorities of the port; but suddenly, without the slightest warning, the ships opened fire upon the imperial arsenal, sank the Chinese gunboats at their anchorage before they could be got under way, and continued the bombardment until the destruction was complete. The action was wholly unexpected, unprovoked by any act of hostility on the part of China, and though the relations of the two countries were strained, diplomatic intercourse had not been interrupted.

A more petty instance of outrage, but one quite as characteristic of the methods pursued by the nations, occurred in 1860, when the foreign legations were established at Peking. The Chinese government leased to the French minister for residence at a nominal rental the unoccupied palace of one of the princes. The gentleman moved in, payed his rent for two years, then claimed ownership and declined to make further remuneration.

The recent acquisition of territory by three great powers is a matter of familiar history. It was accomplished, on the part of Great Britain and Germany, by the use of a formula which has proved in the last forty years to be highly efficacious in extorting valuables from China in a civilized manner and with an appearance of respectability, and has been employed many times. The formula is simple in its nature; equally so in its application. A power demands a concession, usually of some desirable area of harbor frontage, and China, helpless to resist, has no sooner yielded than she has the diplomatic corps about her ears in a frenzy at the disturbance of the "balance of power." Each diplomat waves a claim for indemnity, and China, thoroughly cowed by long experience, must restore the balance by further cession of property, or by the payment of an equivalent in gold. Thus, at the end of the Chinese-Japanese war, the victor restrained by concert of Russia, France and Germany from holding Manchuria as the fruit of conquest, had hardly evacuated Port Arthur before the place was occupied by the

forces of the Czar, and with reiterated assurances of a perfectly honorable purpose to presently withdraw, they commenced the absorption of the 400,000 square miles which Japan had been forced to relinquish. At once Germany and England discovered that the "balance of power" had been deranged to a degree that required the cession of Kiao-chau to the one, and of Wei-hai-wei to the other. The balance of power! Unhappy China!

But all these injuries, inflicted upon the most inoffensive race of people on earth, accompanied as they have been by every form of diplomatic bullying, coercion and insult, and not infrequently by armed invasion, sink into inconsequence in comparison with the superlative infamy of the opium trade forced upon her by Great Britain. For centuries the production and use of the drug had been prohibited in the empire and punished with the utmost severity; but in 1773 the British East India Company, which had the monopoly of the article in India, smuggled a small shipment into the province of Kwang Tung. The profits of the enterprise proved to be great, and by the end of the century, notwithstanding the endeavors of the Chinese authorities to suppress it, the illicit trade had grown to important proportions. The government at Peking placed heavy penalties upon the importation, but through bribery and intimidation of the customs officials the traffic rapidly increased, and regular lines of swift, heavily armed schooners and junks set the laws at defiance. On the expiration of the charter of the East India Company in 1834 the opium monopoly fell into the hands of the British government, which took up the business with energy and protected it with the guns of a powerful fleet. Under these auspices the smuggling continued with practical impunity until at last, thoroughly alarmed at the rapid growth of the vice which was fastening itself upon his subjects in spite of the penalties of transportation or death for its indulgence, the Emperor ordered one of his most vigorous officers, Commissioner Lin, to stop the trade at whatever cost. In 1839 this officer seized and destroyed at Canton an amount of opium worth \$9,000,000, and exacted from the dealers, Chinese and foreign, pledges that they would not resume the traffic. But by this time Great Britain was deriving an annual revenue of over seven million dollars from the smuggling, and outraged by the high-handed action of the Chinese government in venturing to enforce its own laws, promptly sent a military force to demand reparation. The war was disastrous to China, and she was whipped into a treaty of "amity and commerce," compelled to cede Hong Kong to the British, and to pay \$23,000,000 indemnity. The warning was ample, and the imperial officials dared offer no further hindrance to the admission of the "foreign devil's dirt." Even this condition of affairs was unsatisfactory to England, however, for the trade was still illicit, the goods contraband, and she was placed, by the unreasonable laws of China, in the position

of a smuggler. The situation was not to be borne by any self-respecting nation, and she determined to amend it. The seizure, by Chinese officials, of the "Arrow," an opium schooner owned and manned by natives, but illegally flying the British flag, afforded the desired pretext, and in 1857 Great Britain again declared war. She was joined by the French, and at the end of the campaign, in 1860, China was forced to legalize the opium trade and pay an indemnity of \$11,000,000.

In all the annals of the crimes of nations there is no parallel with this one. In the seventy years since the British East India Company made its first venture with a ship load of the drug, the use of it has spread with appalling rapidity, and its victims are numbered by millions. It has made its deadly inroad upon every social class, bearing destruction of mind and body. China has protested, pled and fought in vain. As a last resort the Emperor wrote a personal letter to Queen Victoria, begging her benevolent aid in suppressing a trade so disastrous to his people, and offering any concession in return. The letter was unanswered, the appeal ignored.

So, we are known to the heathen yellow man as "foreign devils," and the examination halls at Peking have been transformed into a military school!

POE AS AN EVOLUTIONIST

BY FREDERIC DREW BOND

THE career of Edgar Allan Poe was a puzzle to his contemporaries and has been a puzzle to students of his life ever since. Though the mythology with which Griswold and others helped to embellish the poet's biography has been cleared away, the correct summing up of his life seems still far off, and in seeking to find the principle of unity in that strange personality we can but confess ourselves baffled and perplexed. Yet, in estimating Poe's character, one portion of his work may be pointed out on which too little attention has been bestowed. Crude as Poe's philosophic speculations sometimes were, yet foremost among them he entertained, in its broad outlines, that idea of the changes and development of the world which goes, nowadays, by the name of the theory of evolution. To show in what way a recognition of this fact would affect our estimate of him will not be attempted in this paper. It is here proposed simply to exhibit Poe's views on this matter and to point out his place in the list of evolutionary thinkers.

The history of the idea of evolution has been studied by Professor Sully,¹ by H. F. Osborn² and by Edward Clodd,³ but none of them mentions Poe's name in connection with the subject. To "Eureka," the epitome of his thought on this matter, Poe himself attributed the highest value, but his biographers have shown scarcely an inkling of its importance in judging its author. Griswold in his "Memoir of Poe"⁴ remarks on the resemblance of "Eureka" to the once famous anonymous work "The Vestiges of the Natural History of Creation," and Professor Irving Stringham, of the University of California, has a critique on the work inserted in Woodberry's "Life of Poe"⁵ and also in Woodberry and Stedman's edition of Poe's works.⁶ The only article of value, however, on the subject that the present writer knows of is an essay referred to by Mr. Ingram in his "Life of Poe"⁷ by Wm. Hand Browne, entitled "Poe's Eureka and Some Recent Scientific Speculations," which appeared in *The New Eclectic Magazine in*

¹ "Encyclopedia Britannica," Art. "Evolution," Part II., Vol. VIII., p. 351.

² "From the Greeks to Darwin."

³ "Pioneers of Evolution."

⁴ Page xliii.

⁵ Pages 286-301.

⁶ Vol. IX., pp. 301-312.

⁷ Vol. II., pp. 148, 296. Notice also the first paragraph in the introduction to Vol. XVI. of the Virginia edition of Poe's works edited by Jas. A. Harrison.

1868. It appears to have produced no permanent impression. Poe seems to have put certain of his ideas before scientific men during his lifetime, but received no encouragement. Commenting on a letter from the present writer on "Eureka," published in the *Times Book Review*, of Philadelphia, Mr. Henry Newton Ivor of that city wrote, under date August 21, 1901, to that periodical:

My father, who knew the poet during his connection with William Burton, often told me that Poe had met with rebuffs from scientific men to whom he undertook to explain his belief in the development of things.

To get to the starting point of Poe's speculations we should perhaps, go back to his youth, when we find him under the double influence of the eighteenth-century French philosophers and of Coleridge and Schlegel.⁸ But how far these two streams of thought colored Poe's philosophy is not easy to say. Most of his speculations seem determined by the facts of contemporary science and his own intellectual activity. Not till his later years do we find any extensive expression of his views. "The Colloquy of Monos and Una,"⁹ "The Island of the Fay,"¹⁰ and "Mesmeric Revelation"¹¹ are some of the pieces in which he appears as a speculative thinker. But not till 1847, two years before his death, does he appear to have tried to form a definite system for himself. Early that year his dearly-loved wife died and her death seems to have impelled his mind towards attempting to unravel "the riddle of the universe." Throughout the fall and winter of that year he elaborated his thoughts,¹² and on February 3, 1848, an abstract of his speculations was delivered as a lecture at the Society Library of New York.¹³ Shortly afterwards it was published by Putnam under the title "Eureka."

Nothing better exhibits the intense belief of Poe at the time in the truth of his theories than the account given by Mr. George Putnam of their strange interview in regard to the publication of the work. According to this account, a gentleman one day entered the publisher's office in a nervous and excited manner and requested his attention to a matter of the greatest importance.

⁸ The evidence for these statements is largely based on inferences from the contents and citations of Poe's works, taken in connection with their dates of composition. A fragment of direct evidence in regard to the eighteenth-century writers may be found in Ingram, Vol. I., p. 52. The great influence of Coleridge on Poe is admitted on all hands. Cf. Woodberry's "Life," pp. 91-93.

⁹ Published in 1841.

¹⁰ Published in 1841.

¹¹ Published in 1844.

¹² See the interesting account, derived from Mrs. Clemm, in Didier's "Life."

¹³ For contemporary newspaper notices of the lecture see Woodberry and Stedman's edition of Poe's works, Vol. IX., pp. 312-315. "All [the papers] praised it," says Poe in a letter to a correspondent, "—as far as I have yet seen—and all absurdly misrepresented it." Ingram, Vol. II., p. 140. He excepts partially an article in the "Express," Virginia edition, Vol. I., p. 277

Seated at my desk, says Mr. Putnam, and looking at me a full minute with his "glittering eye," he at length said, "I am Mr. Poe." I was "all ear," of course, and sincerely interested. It was the author of "The Raven" and of "The Gold Bug." "I hardly know," said the poet, after a pause, "how to begin what I have to say. It is a matter of profound importance." After another pause, the poet seeming to be in a tremor of excitement, he at length went on to say that the publication he had to propose was of momentous interest. Newton's discovery of gravitation was a mere incident compared with the discoveries revealed in this book. It would at once command such unusual and intense interest that the publisher might give up all other enterprises, and make this one book the business of his lifetime. An edition of fifty thousand copies might be sufficient to begin with, but it would be but a small beginning. No other scientific event in the history of the world approached in importance the original developments of the book. All this and more, not in irony or jest, but in intense earnest—for he held me with his eye like the Ancient Mariner. I was really impressed, but not overcome. Promising a decision on Monday (it was late Saturday), the poet had to rest so long in uncertainty, upon the extent of the edition, partly reconciled by a small loan meanwhile. We did venture, not upon fifty thousand, but five hundred.¹⁴

This account, which was written twenty years after the events it relates, seems more or less colored;¹⁵ it exhibits, however, sufficiently well, the value attached by Poe to his work.

At the opening of "Eureka" Poe thus states his purpose:

I design to speak of the Physical, Metaphysical and Mathematical—of the material and spiritual universe,—of its Essence, its Origin, its Creation, its Present Condition and its Destiny. I shall be so rash, moreover, as to challenge the conclusions, and thus, in effect, to question the sagacity, of many of the greatest and most justly revered of men.¹⁶

Following this, comes a satire on the exclusive use of either the deductive or inductive methods in the search for truth, purporting to be written by a student of our logic, a thousand years hence.¹⁷ The skit is clever and is not wanting in some telling hits, but it is out of place and has probably caused many a reader to put down the whole essay. Then after some acute criticisms of a few metaphysical terms, such as "Infinity" and a "First Cause,"¹⁸ Poe proceeds to his main theme. "In the beginning," from "his spirit or from nihility," "by dint of his volition," God created a single material particle in a condition of the utmost possible unity and simplicity.¹⁹ "The assumption of absolute unity in the primordial particle includes that of infinite divisibility. Let us conceive the particle, then, to be only not totally exhausted by diffusion into space. From the one particle, as a center,

¹⁴ *Putnam's Magazine*, October, 1869. Quoted by Ingram, Vol. II., p. 145.

¹⁵ Both Ingram (Vol. II., p. 144) and Woodberry (p. 285) are of this opinion.

¹⁶ 'Works,' Vol. IX., p. 5.

¹⁷ Works, edited by Steadman and Woodberry, "Eureka," Vol. IX., pp. 7-18. This edition of Poe's works is referred to throughout the references in the present article.

¹⁸ *Ibid.*, pp. :0-24.

¹⁹ Pages 26, 27.

let us suppose to be radiated spherically—in all directions—to immeasurable but still definite distances in the previously vacant space—a certain inexpressibly great yet limited number of unimaginably yet not infinitely minute atoms.”²⁰ Differences of size and form taken conjointly cause differences of kind among these atoms.²¹

The natural tendency of these subdivisions of matter is towards the unity whence they sprang. On the fulfilment of the radiation, the diffusive energy being withdrawn, to avert this tendency, and the consequent absolute coalition of the atoms, repulsion makes its appearance.²² These two principles, attraction and repulsion, being the “sole properties through which we perceive the universe,” “we are fully justified in assuming that matter exists only as attraction and repulsion—that attraction and repulsion are matter, there being no conceivable case in which we may not employ the term “Matter,” and the terms “Attraction” and “Repulsion,” taken together, as equivalent, and therefore convertible, expressions in logic.”²³ The nature of repulsion Poe refuses to attempt to determine, but he states it to be identical with electricity. To it we should probably refer the various physical appearances of light, heat and magnetism, and still more so the phenomena of vitality, consciousness and thought. Attraction is the material, repulsion the spiritual principle of the universe.²⁴ As Poe declares that both together constitute matter, he thus states a sort of crude monism.

Since the diffused matter was radiated in a generally equable manner, we may conceive it as arranged in concentric spherical strata about its origin. This at once leads us to the explanation of the mode in which attraction acts—the reason, that is, why gravitation varies inversely as the square of the distance between the attracting masses. For, since the surfaces of spheres vary as the square of their radii, the number of atoms in each concentric spherical stratum is proportional to the square of that stratum’s distance from the center. But as the number of atoms in any stratum is the measure of the force that emitted that stratum, that force itself is directly proportional to the square of its stratum’s distance from the center. Now, on the fulfilment of the diffusion, the *modus operandi* of the attractive force is, of course, the converse of that of the diffusive; in other words, each particle of matter seeks its original condition of unity by attracting its fellow-atoms with a force inversely proportional to the square of the distances between them.²⁵

²⁰ “Eureka,” p. 28.

²¹ Pages 29, 30.

²² Pages 31–33.

²³ “Eureka,” pp. 34, 35.

²⁴ Page 34.

²⁵ “Eureka,” pp. 35–66. In a MS. note, referring to the diffusion, Poe says: “Here describe the process as one instantaneous flash.” (Page 52.)

Matter being thus distributed, attraction causes it to aggregate in nebulous patches, which proceed to undergo a development similar to that described in Laplace's "Nebular Hypothesis." Our solar system, beginning in the form of a nebula, assumed a spherical shape and, as its constituent atoms sought its center, began to revolve. As the velocity of the revolution increased, the "centrifugal force" got the better of the centripetal, and a ring of matter was detached from the nebula's equator; this ring finally condensed into the planet Neptune. Shrinking in size, the nebula, in like manner gave birth to the other planets, including the earth, and finally arrived at the size in which we now know it as the sun. Similarly, during their condensation, several of the planets threw off satellites.²⁶

In the following paragraphs Poe sums up the cosmic development and gives an account of the changes on the earth's surface:

In speaking, not long ago, of the repulsive or electrical influence, I remarked that "the important phenomena of vitality, consciousness and thought, whether we observe them generally or in detail, seem to proceed at least in the ratio of the heterogeneous." I mentioned, too, that I would recur to the suggestion; and this is the proper point at which to do so. Looking at the matter, first, in detail, we perceive that not merely the manifestation of vitality, but its importance, consequences, and elevation of character, keep pace very closely with the heterogeneity or complexity of the animal structure. Looking at the question, now, in its generality, and referring to the first movements of the atoms towards mass-constitution, we find that heterogeneousness, brought about directly through condensation is proportional with it forever. We thus reach the proposition that the importance of the development of the terrestrial vitality proceeds equably with the terrestrial condensation.

Now, this is in accordance with what we know of the succession of animals on the Earth. As it has proceeded in its condensation, superior and still superior races have appeared. Is it impossible that the successive geological revolutions which have attended, at least, if not immediately caused, these successive elevations of vitallic character—is it impossible that these revolutions have themselves been produced by the successive planetary discharges from the sun; in other words, by the successive variations in the solar influence on the Earth? Were this idea tenable, we should not be unwarranted in the fancy that the discharge of yet a new planet, interior to Mercury, may give rise to a new modification of the terrestrial surface—a modification from which may spring a race both materially and spiritually superior to man.²⁷

The statement of Poe in this passage, that "heterogeneousness, brought about directly through condensation, is proportional with it forever," appears to contain the germ of Herbert Spencer's developed formula: "Evolution is a change from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity through continuous differentiations and integrations."²⁸ Noteworthy, also, is Poe's statement of the correlation between mental development and physical organization.

²⁶ Pages 66 et seq.

²⁷ "Eureka," pp. 80, 81.

²⁸ This is the form in the 1862 edition of "First Principles." In the later editions the formula reads: "Evolution is an integration of matter and concom-

The most interesting point about the whole passage, however, is probably that connected with Poe's ideas on the origin of animal organisms. Is he here stating the true theory of the descent of each from lower forms? Or, is his view a revival of that held by several Greek philosophers and in modern times by Duret and Oken, of the direct production of species by natural causes?²⁹ In Poe's tale "Some Words with a Mummy," published in 1845, the resuscitated Egyptian replies to a query concerning the creation, thus:

During my time I never knew any one to entertain so singular a fancy as that the universe (or this world, if you will have it so) ever had a beginning at all. I remember once, and once only, hearing something remotely hinted, by a man of many speculations, concerning the origin of the human race, and by this individual the very word Adam (or Red Earth), which you make use of, was employed. He employed it, however, in a generical sense, with reference to the spontaneous germination from rank soil (just as a thousand of the lower genera of creatures are germinated)—the spontaneous germination, I say, of five vast hordes of men, simultaneously upspringing in five distinct and nearly equal divisions of the globe.³⁰

How far this is jest and how far earnest is hard to say.

Of the mental development of man, Poe does not speak in "Eureka." From passages elsewhere (chiefly in "Marginalia") he seems to have thought humanity had progressed along religious, scientific and esthetic lines, but pessimistic remarks of an opposite character are not wanting in his writings.

The only passage elsewhere which alludes to the subject is contained in a letter, written shortly after the publication of "Eureka" to the editor of the "Literary World" in answer to some strictures a correspondent had made on the work. It reads as follows:

"The third misrepresentation lies in a foot-note, where the critic says: 'Further than this, Mr. Poe's claim that he can account for the existence of all organic beings—man included—merely from those principles on which the origin and present appearance of suns and

itant dissipation of emotion: during which the matter passes from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity; and during which the retained motion undergoes a parallel transformation." "First Principles," p. 334. There seems to be considerable correspondence between Poe's "condensation" and Spencer's "integration."

²⁹The following extract from Oken deserves to be cited as showing how, in any event, Poe's views were as reasonable as those propounded by one regarded as a forerunner of Darwin: "Man also is the offspring of some warm and gentle seashore, and probably rose in India, where the first peaks appeared above the waters. A certain mingling of water, of blood warmth, and of atmosphere, must have conjoined for his production, and this may have happened only once and at one spot." Quoted by H. F. Osborn, in his work "From the Greeks to Darwin," p. 127. Among the Greeks who propounded the hypothesis of the direct natural production of organisms from the elements were Thales, Anaxagoras and Empedocles.

³⁰"Works," Vol. II., p. 301.

worlds are explained, must be set down as mere bald assertion, without a particle of evidence. In other words, we should term it arrant fudge.' The perversion at this point is involved in a wilful misapplication of the word 'principles.' I say 'wilful,' because at page 63 I am particularly careful to distinguish between the principles proper, Attraction and Repulsion, and those merely resultant subprinciples which control the universe in detail. To these subprinciples, swayed by the immediate spiritual influence of Deity, I leave, without examination, all that which the student of theology so roundly asserts I account for on the principles which account for the constitution of suns, etc."³¹ This passage, it is plain, is as indecisive as the text of the essay. On the other hand, one with Poe's wide knowledge can hardly, it would seem, have lacked knowledge of Lamarek's theories, nor was he ignorant of the then recent work, "The Vestiges," though he had not then actually read it (in a letter to Geo. E. Isbell, he inquires how far "Eureka" is at one with the "Vestiges"³²). But Poe's interest does not seem to have centered on what would be now termed the biological side of the matter.

Having described the development of the universe, Poe, in passages whose sweep and power remind one of Tennyson's "Vastness," proceeds to set before us its present condition and immensity.³³ Then, finally, he pictures the inevitable dissolution of it all, when stars and planets will at length lapse into the substance of one central orb. Here attraction will finally predominate over repulsion, complete unity obtain, and matter without attraction and repulsion will again sink "into that Material Nihilicity from which alone we can conceive it to have been evoked, to have been created, by the Volition of God."³⁴ The outcome of the whole process Poe sums up in the following words, in which he restates the old doctrine of the universe as being in a state of perpetual flux:

On the universal agglomeration and dissolution, we can readily conceive that a new and perhaps totally different series of conditions may ensue; another creation and radiation, returning into itself, another action and reaction of the Divine Will. Guiding our imagination by that omniprevalent law of laws, the law of periodicity, are we not, indeed, more than justified in entertaining a belief—let us say, rather, in indulging a hope—that the processes we have here ventured to contemplate will be renewed forever and forever and forever; a novel universe swelling into existence, and then subsiding into nothingness, at every throb of the Heart Divine?³⁵

For, in this everlasting metamorphosis, every "creature"—to use Poe's term—both those we call living, and those to which we deny the

³¹ Griswold, p. xlv.

³² Virginia edition, Vol. I., pp. 277, 278.

³³ "Eureka," pp. 81 et seq.

³⁴ "Eureka," pp. 115-133.

³⁵ "Eureka," pp. 133, 134.

name, because we do not perceive the vital operations, are all, in a measure, possessed of life and consciousness. The cosmos is, as it were, composed of cycles of minds within cycles, the less within the greater, and all within the Divine Spirit, unto which all things, on their dissolution, return.³⁶

From the preceding sketch, it will be evident that, in its important features, "Eureka" is a prevision of the modern doctrine of evolution. In the statements that the universe is in a perpetual flux, that it is now evolving and will in the future dissolve, that it has developed from a condition of homogeneity, and that our own system sprang from a nebula, Poe is in accord with the Spencerian philosophy and very probably with the actual facts; while in the assertions that the earth has, during successive geological ages, produced a higher and higher organic life characterized by an ascending development of mind, hand in hand with an increasing complexity of the physical organization, he is stating what are now known to be simple scientific facts. Erroneous, of course, the details of his conceptions very frequently are;³⁷ but this is common to him with the pioneers of every great idea. Only in the course of time does the germ of truth they discover attain its full growth and reveal its true character. To criticize "Eureka" from a contemporary standpoint would be as beside the mark as to treat the "Naturphilosophie" of Schelling or of Hegel in the same way.³⁸ It was a remark of John P. Kennedy, Poe's old friend, that the latter "wrote like an old Greek philosopher" and any one who reads the fragments of the Greek thinkers before Aristotle can easily verify for himself the truth and aptness of the statement. The merits of Poe, in common, more or less, with the other pre-Spencerian evolutionists lie in how far and how truly his genius enabled him to divine the mode of development of the universe.

Owing to the causes pointed out at the beginning of this paper, it is improbable that "Eureka" had any influence in preparing the way for the reception of evolutionary ideas, a little later; at the most such influence must have been of the slightest, for though this work was early translated into foreign languages, the failure to find fitting recognition of its true character, and the general obscurity in which it has lain, seem to preclude any such likelihood. Its interest lies in the light it throws on its author and in the honorable place to which it assigns him in that long line of thinkers from Thales to Darwin.

³⁶ *Ibid.*, pp. 134 ad fin. lib.

³⁷ It may be added that 'Eureka' contains some implicit contradictions also, due apparently, to an advance in the author's thought.

³⁸ Nor is it any exaggeration to say that Spencer's "First Principles" is far from immune from heavy critical attacks (as witness J. Ward's "Naturalism and Agnosticism") and that it is literally true that the scientific eminence of Spencer's work over "Eureka" lies more in its form than in its contents.

MARS AS SEEN IN THE LOWELL REFRACTOR.

BY G. R. AGASSIZ

THE writer has lately enjoyed the great privilege, as Professor Lowell's guest, of observing Mars through nearly one presentation,¹ in the great 24-inch refractor.

Few people have had the opportunity of observing Mars at Flagstaff, and there is much scepticism afloat concerning the character of the markings of the planet, more especially as regards the double canals. So the writer proposes to give a short account of what can be seen, in the Lowell refractor, in one presentation, by any one of good eyesight, who is somewhat familiar with the use of a telescope. The writer also wishes to give a description of the methods employed in observing, and the reasons for using them. He will also give a few reasons, which appear to him conclusive, to show that the double canals are actual phenomena, and not the result of diffractive effects in the telescope.

Few astronomers appear to realize how exceptionally excellent the seeing is in the clear dry air of Flagstaff, on a quiet night. It is so good, in fact, that a comparative novice appears to be able to see the planet more distinctly in one presentation there than Schiaparelli, at Milan, ever did.

During the time of the writer's observations, the diameter of Mars increased from 12" to 18". The eyepiece used in observing was usually a 25 mm. orthoscopic, Zeiss, which gives a remarkably large flat field. This gives, on the 24-inch refractor, a power of 393. So that the apparent size of the disk of Mars was about 2.6 times the diameter of the Moon, as seen by the naked eye, at the beginning of the writer's observations, and 3.9 times at the end.² This is amply large enough to distinguish a vast amount of detail, when the seeing is sufficiently good to disclose it. Sometimes, when the seeing was unusually good, an eyepiece of 20 mm. would be tried, giving a power of about 490; but this was rarely used to advantage. When the seeing required a less power than the 25 mm., the planet could not be observed satisfactorily.

A circular disk was fitted over the eyepiece, containing an assortment of orange-yellow, and neutral-tinted glasses; any one of these could, at will, be revolved in front of the eyepiece. These glasses serve in a marked degree to bring out the contrasts on the planet.

¹ From April 28 to June 2, 1907.

² With this power Mars appears about 5.2 times the diameter of the moon, at opposition in 1907.

How little effect chromatic aberration plays in the observation of planetary detail may be judged from the fact that all the observers at Flagstaff preferred a neutral-tinted glass to a monochromatic one.

The action of a shade in bringing out detail appears to be somewhat as follows: In viewing a point of light through a telescope of a given aperture, the first minimum of the curve of diffraction, or the middle of the first *dark ring*, will always be at a given distance from the point of light, but the spurious disk will fade away, out of sight, before it reaches the minimum; and the fainter the point of light, the smaller the spurious disk. As the point of light approaches invisibility in the telescope, the spurious disk approaches zero. Now suppose we consider the light bordering a dark line on Mars as made up of numberless points of light. These points of light are excessively faint, compared with points of light on the sun, or with the light from a star. Their spurious disks are therefore extremely small, so that very little light spills over on to the dark markings; and that is the reason we are able to make out such fine detail on the planet. Now, although small, the spurious disks of these numberless points do diffuse some light on the fine dark markings. By using a shade, we decrease the light from these points, and thus reduce the size of their spurious disks. Therefore less light falls on the dark markings, and the sharpness of their edges is increased.

It is further found at Flagstaff that diaphragming the aperture increases the seeing. Langley, in his article on soaring birds, has shown that there are constant small changes of velocity "within the wind." Now these pulsations must cause waves of rarefaction and condensation, which may be represented as an irregular wave curve, sweeping past the objective. This will cause the planet to swing in the field of the telescope, as the rays are refracted by a layer of denser or rarer air. Now it is evident that the smaller the aperture of the objective, the less variation of the curve will there be in front of the objective at any given instant, or the more homogeneous the air in the path of the rays entering the eye at any given moment. So that, though a smaller objective will not diminish the swinging of the planet in the field, it will diminish the blurring within the planet, and help bring out the detail. Thus, the smaller the objective, the better the seeing, other things being equal. In practise the best results were obtained with a 12-inch diaphragm, as below this the loss of light and of effects due to increasing the size of the spurious disk began to be more powerful factors than the advantages gained from better seeing.

So importantly essential are the shaded glass, and the diminution of the aperture to the study of Martian detail at Flagstaff, that without these aids it would be excessively difficult to make out any of the fine detail on the planet.

It is a mistake to suppose that an observer who has a very keen sight for a small star will necessarily be a good observer of planetary

detail. Indeed it often seems to be the reverse; as if an eye, sensitive to light, were not as acute for form. Now it is well known that no two objects can be separated by the human eye that do not fall on more than one cone in the fovea, or central pit of the retina. So may it not be that an eye, very sensitive to light, has unusually large cones in the fovea, while one acute for form has small ones?

There seems to be a great reluctance to accept the finer markings on Mars as established facts, and their objective reality has been questioned by all kinds of doubts and theories by all sorts of men. It might be well if some people, who explain away the markings on the supposition that they are optical illusions, would take the trouble to follow up their theories, see where they lead to, and work out what the appearance of the markings would be if due to the causes they suggest.

A Professor Douglass, of Arizona, has lately suggested that the canals are nothing but the black rays that can be seen radiating from a black spot, on a light ground, when looked at with a small screen placed in front of the pupil of the eye, so that the light enters only around the edges. According to Professor Douglass, the black oases are the only real things in the canal system, while the canals themselves have no tangible existence, and are nothing more than these black rays issuing from the dark spots.

In the first place, no eyepieces, constructed on any such principles as Professor Douglass uses to see these rays, are known at Flagstaff. Furthermore, the oases are more difficult objects to see than the canals. The latter are often visible when the former are not. It would seem that even Professor Douglass should find it hard to admit that, at such times, the canals are visible radiations from invisible spots.

But let us see what the canals would look like if actually due to this cause. These radiations are due to irregularities in the crystal-line lens, and are constant for an adult, but vary with each individual. So that any one, looking at the planet, would see an exactly similar set of radiations issuing from each oasis. The planet would be covered with a quantity of black spots, all with similar radiations, and all absolutely independent of each other. For no two radiations from different spots would ever, except by the rarest chance, run into each other to form a straight unbroken line, connecting the two spots. The radiations would also be entirely different for each individual. As one of the most striking features of Martian detail is the manner in which the canals connect and interlace the oases, further comment seems unnecessary.

It has also been suggested that the so-called canals may not be lines at all, but merely a disconnected string of broken markings, a sort of irregular dotted line.

A series of observations at Flagstaff, conducted by several individuals, has shown that the eye is extremely sensitive to a break in a line.

A series of lines, .3 mm. wide, was viewed from a distance of 17 feet. Each line was made up of 10 mm. sections, separated by small intervals that were the same between the sections of each line, but differed for every line. It was found that a line, whose sections were .5 mm. apart, was visible as a discontinuous line. A line with the sections .25 mm. apart appeared continuous.

With the power usually used at Flagstaff, the first figures would correspond on the planet at opposition to a line five and a half miles wide³ visible as a discontinuous line, if the sections were eight miles apart. That the Martian markings should be composed of a series of dotted lines, separated by intervals never greater than eight miles, would seem far more wonderful than the canals themselves.

There is a wide-spread feeling that the double canals are due to diffractive effects in the telescope. The writer wishes to state, at some length, why it appears to him that this can not be the case.

The writer has made many experiments, with various telescopes, on dark lines on a light field viewed by reflected light. In no case has he been able to detect diffractive effects that in any way resemble the double canals of Mars, as seen in the Lowell refractor, while, on the other hand, parallel lines, close together, bear a striking similarity to the double canals.

In dealing with this subject, it is surprising to find how little is really known of diffractive effects caused by a dark line on a light field. This is the gist of the whole matter, and is a very different thing from the well-known effects of diffraction obtained when viewing a point, or a line, of light on a dark field.

In viewing a luminous point on a dark field through a given telescope the distance of the rings of diffraction from the center of the spurious disk may be easily found from the formula $\phi = \frac{c\lambda}{r}$, where ϕ is the angle measured from the objective to the focus; c is a constant for each maximum or minimum; λ is a wave-length, and r is the radius of the objective. Now the second maximum, or the radius of the first bright ring, measures about $0''.31$ in the Lowell refractor. If we extend this point to form a line, the ring will be transformed into

³ Various observers have experimented at Flagstaff at different times with wires stretched against the sky, viewed at ever increasing distances. The distances at which a wire was distinctly visible varied with different individuals, and corresponded to an angular width for the wire varying from $.69''$ to $.93''$. Looking at Mars at opposition, with a power of 400, these angles would correspond on Mars to widths of from 0.31 to 0.42 miles. Making all possible allowance for loss of light, etc., in the telescope, it seems probable that, under favorable circumstances, a line less than a mile wide could be detected on the planet. By comparison with the finest micrometer threads, some of the single canals are estimated to be as much as 35 miles wide. The width of the various double canals, which remains constant for each canal, is estimated to range from 2° to 5° on the planet. This is found, by various terrestrial experiments at Flagstaff, to be far wider than lines that can be easily separated by the eye.

two lines, one on each side of the source of light, at a distance of $0''.31$ from it, and, since the second maximum has but $.017$ the intensity of the first, the outlying lines will be but $.017$ of the brilliancy of the central one.

On Mars we have to consider dark lines on a light field, and little seems to be known of their diffractive effects. There is a disposition to assume that we are here dealing with an inverted diffraction curve. Personally, it seems to the writer that there is no similarity between a bright line, whose light waves produce diffractive effects, and a dark line that emits no light waves. But let us assume that, somehow, the dark line on a light field will produce the same diffractive effects as a light line on a dark field. Then, were the double canals due to this diffraction, they would appear as follows on the planet, when seen in the Lowell refractor. Each and every canal would appear triple, the outer lines would always be separated by $0''.31$ from their primary, and be $.017$ less distinguishable than it. Furthermore, there would be a dark ring around every oasis. No triple canal has ever been observed on Mars, nor has any ring ever been seen around an oasis.

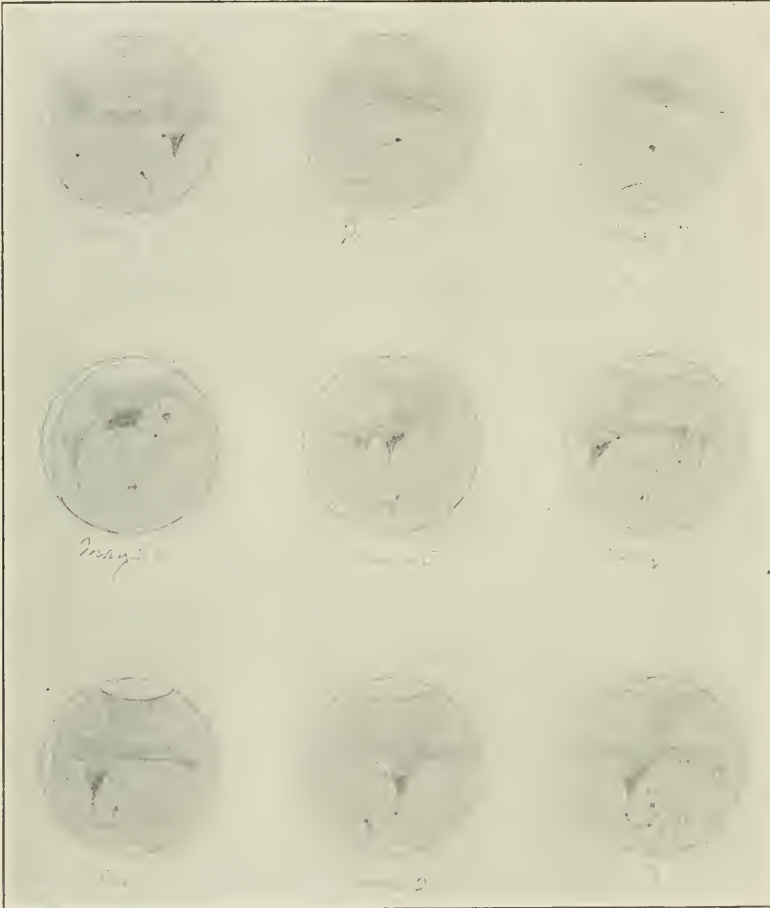
The distance from the first minimum to the second maximum on the diffraction curve measures about $''.$ 08 in the Lowell refractor. Now if the double canals were dark bands of a width of $''.$ 16 , then the points of light on the planet, at such a distance from the band that their first minima fell on its edge, would cast the light of their second maxima in the center of these bands, and these maxima, from the points on each side of any band, would overlap.

It is conceivable that such an effect might look something like a double canal, were it not for the fact that the diffracted light from all the other neighboring points of light would swamp and drown any such illusion. Supposing, however, that the double canals were really such dark bands, illuminated in their centers by the second maxima of the fringing light, then the double canals would always appear very nearly $0''.16$ apart, which would correspond to about $1^\circ.5$ on the planet, when its diameter was $12''$. But as the planet approached, since the distances apart of the maxima and minima in the focus of the telescope remain constant, the widths of the bands would no longer fit them, and the effect would be lost. Thus it follows that these bands of uniform width could never appear double, except at one given distance of the planet.

There are certain rules that the double canals should observe if they were due to diffraction, but they follow none of these. They should (since the size of the rings of diffraction remain constant through a given aperture) appear nearer together, in degrees on the planet, as Mars approaches; instead of which they remain the same size. They should (as diffractive effects vary in size inversely as the radius of the objective), as the objective is diaphragmed down, appear

farther apart; but in fact diaphragming has no effect on their width. Not only should all the canals appear double, but they should all seem the same width. Less than one eighth of the canals have ever been seen to be double; and the double canals vary from each other in width, ranging from 2° to 5° .

In drawing A: 1 (the Euphrates) appears much wider than 2 (the Astaboras), while 3 (the Protonilus) is narrower than either; 4 (the



Vexillum), which is a double canal, the writer was unable to resolve, but he could never have classed it with 5 (the Astrusapes). This last appeared as a sharp dark pencil mark, as, indeed, do all the single canals, when the seeing is really good. The double canals then come out like the lines of a railway track seen from a half-distant hill.

If the double canals are really due to diffractive effects, how is it that only those are able to distinguish them whose eyesight is sufficiently good to obtain an exceptional view of the planet? Should not any one who can see the single canals be able to see them double?

However, these remarks are probably quite useless. No one of good eyesight, who has seen Mars at Flagstaff, on a night when the seeing is really good, needs any arguments to convince him that what he sees is real. And no one who has made up his mind beforehand, without seeing them, that the double canals are due to diffraction, is likely to be influenced by these words.

It would seem almost unnecessary to state that no one for a moment supposes that the lines that one sees are actual streams of water. They are thought to be broad stretches of vegetation, dependent on channels of water running through them. So would the valley of the Nile appear to a distant observer, who would distinguish the dark fertile valley against the sands of the desert, long before he could see the river itself.

During the writer's visit to Flagstaff, he saw 77 canals, 20 oases, and 11 double canals,⁴ all of which, with one exception, could be readily identified on some one of Lowell's maps, though it was sometimes necessary to consult a map of an earlier date than the opposition of 1905, to find them. Each of the drawings is the accumulated result of some 15 or 20 minutes at the telescope, so that no one of them represents everything seen in a single night.

It must not be imagined that any drawing represents what the observer sees the moment he looks through the telescope. Instants of exceptional seeing flash out, here and there, at different spots on the planet. It is not till the same phenomena repeat themselves in the same way, in the same place, a great number of times, that the observer learns to trust these impressions. One has to keep one's mind constantly at the highest pitch to catch and retain what the eye sees.

It is like looking at a Swiss landscape from a high Alp, with the summer clouds sweeping about one. Now the mist rolls away, revealing a bit of the valley, and shuts in again in a moment; while in some other spot the clouds break away, and disclose a jagged summit, or a portion of a shining glacier.

Any one who has been fortunate enough to have had a really good view of the lineal markings on Mars is bound to be much impressed by their artificial appearance. So that, unless he has an inborn prejudice against the idea, any theory that accounts for the canals as the effort of intelligent beings to accomplish some definite object will not appear fanciful.

Lowell's theory that we have here evidence that the inhabitants of

⁴There are known at present 436 canals, of which 51 are double, and 186 oases. These are never all seen at one opposition, not only because of the different tilts of the planet, but also because neighboring canals alternate in appearing and disappearing at different oppositions. Accepting Lowell's theory that the canals are areas of vegetation bordering artificial channels for irrigation, this could be accounted for by the fact that when the canals do not appear, the land is lying fallow.

Mars are struggling to preserve their existence by a planet-wide system of irrigation seems to be gaining ground; although he has had to contend against something of the same opposition that confronted Copernicus, Bruno and Galileo, and for very much the same reasons. The human mind resents anything that tends to belittle it, or its surroundings, and will not tolerate the idea of a rival.

It would seem, in all fairness, that a theory that fits all the observed facts as beautifully as Lowell's does deserves something better than disdainful disrespect, even from the most conservative. It is certainly far better than any theories and objections that do not meet the facts at all. As yet no other theory has been suggested that in any way accounts for the Martian markings. Until one is evolved that accounts for the facts better, Lowell's theory should be accepted, by the most sceptical, as the only working hypothesis yet devised.

A very noteworthy achievement in the recent study of Mars is the series of remarkable photographs of the planet, taken by Mr. Lamp-land at Flagstaff. Already he has succeeded in photographing many of the canals, and at the date of this writing⁵ he has just photographed the Gihon double.

It seems as if, with the methods at present available, we probably shall not greatly increase our present knowledge of the planet. Even photography will probably be useful chiefly as a means of convincing the sceptical. But who can tell what the future may have in store? What astronomer of the early nineteenth century would have dreamed of the possibility of detecting the composition of the stars, or determining their velocity in the line of sight? Some day a new method may increase our knowledge of Mars, as much as the discovery of the spectroscope opened up the heavens.

To most people "the proper study of mankind is man." But to those of us to whom the fact that we believe we have detected evidence of intelligent life in another planet seems of absorbing interest, Mars appears by far the most fascinating object in the heavens.

⁵ July, 1907.

THE PROGRESS OF SCIENCE

HERMANN VON HELMHOLTZ

THE nineteenth century is distinguished for the advance of science and the spread of democracy, and science is dominant as its applications have supplied the economic conditions that make democracy possible—general education, relative leisure and comparatively broad interests for a majority of the people. We may consequently regard it as probable that the greatest men of the century were its scientific leaders, and that they will ultimately be held in higher honor than the authors or artists, than the statesmen or soldiers. The doctrines of the conservation of energy and of organic evolution are the two greatest generalizations of modern science. Each has had its historical development both before and after, but is primarily associated with the one great name. We may believe that in the future everything connected with the life and work of Helmholtz or of Darwin will be of the deepest interest, and it is fortunate that the biographies that have been published are so adequate. "The Life and Letters of Charles Darwin," by his son, Dr. Francis Darwin, with the supplementary volumes of letters give a sympathetic and vital reflection of the noble and simple man and of his performance. The biography of Hermann von Helmholtz by Professor Leo Königsberger makes a more mechanical impression, but it gives a correct and useful account of the vast range of work accomplished by Helmholtz, and those facts of his private life that can be related objectively.

This biography published in 1902 and 1903 has been abridged and translated into English by Lady Welby, with a preface by Lord Kelvin, and is

now published by the Clarendon Press of Oxford. Of the eight portrait plates in the original, three are reproduced in the translation. In the two portraits by Lenbach the features are somewhat idealized. The bust by Hildebrand, made in 1891, is not given in the English volume, but more truly represents Helmholtz as he appeared during his visit to America toward the end of his life.

The paper on the conservation of energy, printed separately in 1847, after having been rejected by the leading German physical journal, may have been technically anticipated by Mayer and Joule, but it is the cornerstone of modern physical science. When this paper was published, Helmholtz was an army surgeon at Potsdam, his father, who was a teacher of classical languages, not being able to afford the cost of a university education. Thanks to von Humboldt, he was released from the army to become teacher of anatomy in the Berlin Academy of Arts. During his whole life, Helmholtz was deeply interested in the plastic arts, in music and in literature, thus demonstrating that there is no incompatibility between science and the fine arts. Of equal significance is his constant concern with philosophy.

Helmholtz became professor of physiology at Königsberg in 1849; he removed to Bonn in 1855 and to Heidelberg in 1858, remaining there for thirteen years. During this period he measured the velocity of the nervous impulse and prepared his great works on vision and on hearing, of which the ophthalmoscope was a by-product. Helmholtz's primary interests were always in mathematical physics, and he



HERMANN HELMHOLTZ AT THE AGE OF TWENTY-SEVEN. From a daguerreotype taken in 1848, a year after the publication of the paper on the conservation of energy.

consequently welcomed a call to the chair of physics in Berlin. Later he organized and became the first president of the "Reichsanstalt," a national laboratory of physics and technology. During these years, he made his great contributions to thermodynamics and electromagnetism, and with his pupils, Hertz, Lenard and others, gave to mathematical physics its dominant position among the sciences. All the while Helmholtz gave con-

tinually public addresses and popular lectures, and was engaged in commissions of all kinds. The range and quantity of his work are as remarkable as its epoch-making character.

LINNEAN CELEBRATIONS IN SWEDEN

At the beginning of the eighteenth century the military power of Sweden, so long a leading force in European politics, had been crushed, the people



HERMANN VON HELMHOLTZ AT THE AGE OF SEVENTY. A bust made by Adolf Hildebrand in 1891.

had sunk into apathy broken only by intrigue and disorder, the nation was of no account. Then the son of a poor country priest, endowed merely with the divine love of nature and of knowledge, fought his way through school and university, and by constant observation and diligent study of subjects to which neither scholars nor men of the world then paid much attention, won a place among the great ones of

the earth. Installed at Upsala, the youthful Linnaeus first attracted thither students and men of science from all Europe, and then sent them through the whole world as gleaners of further knowledge and ambassadors of his country's new-found fame. Never since has Sweden relapsed from the high place thus won for her among nations in the wider world of scientific thought.



MEDAL IN HONOR OF THE BICENTENARY OF THE BIRTH OF LINNÆUS, STRUCK BY THE SWEDISH ACADEMY OF SCIENCE. The first copy was awarded Sir Joseph Hooker, who celebrated his ninetieth birthday on June 30.

At the beginning of the twentieth century we have seen Sweden apparently losing prestige by the secession of Norway from the union; and, while we have admired the statesmanship that could accommodate itself with dignity to such a severance without the horrors of a brothers' war, we have seen a people mistrustful of its rulers, fearful of its neighbors, and bitter in its own heart. But in this celebration of the most eminent among her sons we may perceive at least one sign that Sweden is recognizing her true greatness. If she did not fully grasp it before, the homage of the world will have forced on her the truth of the Linnean motto—*Fama extendere factis*. Deeds, no longer of arms, but of honest labor in the ever-widening field of science. Sweden has received a blow; but the blow has aroused her. She stands up; she throws off the garment of slumber; she takes in her hand with renewed vigor the weapons of the future. Around the shrine of Linnaeus all classes gathered together, and during those three bright days in a year of rain, as one paced the streets of Upsala and of Stockholm, beyond the celebration of the past, behind the feasts that welcomed spring, one beheld the renaissance of a nation.

How appropriate were the words of Viktor Rydberg's beautiful Cantata as they sounded through the cathedral of Upsala during the impressive promotion of the doctors!

"And yet, if we have fallen down in doubt,
And by the way ye mourn and ponder gravely,
Lift up the banner! flame it out
Once more, and bear it through the desert
bravely!
Care not, though ye perceive with piercing eye
A thousand suns from heaven's archway show-
ering!
Care not, though 'neath the scythe of Time de-
vouring,
Like golden seed the starry harvests lie!
All noble thoughts, all love that leads you on,
All beautiful dreams, Time never can see
wasting;
These are a harvest garnered from his tasting,
'Tis to Eternity that they belong.
Advance Mankind! Be blithe, be of good
cheer;
Since in your breasts ye bear the eternal
here!"

What deep meaning too may one not see in the beautiful medal issued by the Royal Swedish Academy of Science! Here is the nature that the Swedes love so profoundly: the mountains in which are buried vast deposits of ore and fertilizing minerals, the woods and fields still unexhausted of their wealth, the waters with hidden incalculable energy. In their midst observes and ponders the naturalist

who himself did so much to bring these natural treasures to the hands and homes of his countrymen, type of the thinkers who to-day are piercing further secrets and unlocking fresh stores. And there, in a clear sky, rises the sun.

RADIUM EMANATION AND THE TRANSMUTATION OF THE ELEMENTS

SIR WILLIAM RAMSAY has printed in *Nature*, for July 18, a letter, entitled "Radium Emanation," which is the basis of the alleged interviews which have been published in the newspapers. The author states that a full account of his researches will shortly be communicated to the Chemical Society. In his brief statement he calls attention to the fact that with Mr. Soddy he had shown in 1903 that the spontaneous change of the emanation from radium results in the formation of helium; this observation has been confirmed by others. Helium was once detected in the gases evolved continuously from a solution of thorium nitrate. When the emanation is in contact with and dissolved in water, the inert gas which is produced by its change consists mainly of neon; only a trace of helium could be detected.

Sir William now states that when a saturated solution of copper sulphate is substituted for water, no helium is produced; the main product is argon, possibly containing a trace of neon, for some of the stronger of its lines appeared to be present. The residue, after removal of the copper from this solution, showed the spectra of sodium and of calcium; the red lithium line was also observed, but was very faint. This last observation has been made four times, in two cases with copper sulphate, and in two with copper nitrate; all possible precautions were taken; and similar residues from lead nitrate and from water gave no indication of the presence of lithium; nor was lithium detected in

a solution of copper nitrate, similarly treated in every respect except in its not having been in contact with emanation.

According to the author these results appear to indicate the following line of thought: From its inactivity it is probable that radium emanation belongs to the helium series of elements. During its spontaneous change, it parts with a relatively enormous amount of energy. The direction in which that energy is expended may be modified by circumstances. If the emanation is alone, or in contact with hydrogen and oxygen gases, a portion is "decomposed" or "disintegrated" by the energy given off by the rest. The gaseous substance produced is in this case helium. If, however, the distribution of the energy is modified by the presence of water, that portion of the emanation which is "decomposed" yields neon; if in presence of copper sulphate, argon. Similarly the copper, acted upon by the emanation, is "degraded" to the first member of its group, namely, lithium; it is impossible to prove that sodium or potassium are formed, seeing that they are constituents of the glass vessel in which the solution is contained; but from analogy with the "decomposition-products" of the emanation, they may also be products of the "degradation" of copper.

SCIENTIFIC ITEMS.

WE record with regret the deaths of Professor Angelo Heilprin, the eminent naturalist and explorer, professor of paleontology and geology in the Philadelphia Academy of Natural Sciences and lecturer in physical geography at Yale University; of Dr. William L. Ralph, curator of the Section of Bird's Eggs, in the U. S. National Museum; of Sir William Henry Broadbent, F.R.S., a leading London physician; of Dr. August Dupré, F.R.S., chemical adviser to the explosive department of the Home Office of the British govern-

ment, and of Dr. Heinrich Kreutz, associate professor of astronomy at Kiel and editor of the *Astronomische Nachrichten*.

THE tercentenary of the death of Ulisse Aldrovandi, the celebrated naturalist, was celebrated at Bologna, from June 11 to 13, in the presence of numerous delegates from foreign countries. A memorial tablet was unveiled, while a medal and several volumes compiled for the occasion were presented to the delegates.

THE Norwegian Storting has voted the sum of 40,000 Kroner to Mr. Roald Amundsen in recognition of his services to science in traversing the northwest passage and relocating the magnetic North Pole.—Dr. Otto Zach-

arias, director of the Biological Station at Plon, and Dr. C. G. Schillings, the African traveler, have been given the title of professor by the German government.—Professor W. F. M. Goss, dean of the Schools of Engineering and director of the Engineering Laboratory of Purdue University, has accepted the position of dean of the College of Engineering in the University of Illinois.

THE Royal Society of Medicine, composed by a union of medical societies in London, has received a royal charter. The society begins with a membership of 4,000 and an income of \$40,000. Sir William Church has been elected the first president of the society.

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A TRIP AROUND ICELAND

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THE study of islands, whether the attention of the visitor is directed to their structure or their inhabitants, yields a peculiar pleasure. They are quite definite and unique units. They reveal interesting relations with neighboring continents, of which they so often are merely separated fragments, and they afford texts for suggestive and fascinating speculations as to past geographical conditions.

In their life no less than in their mineral features, they exhibit to the naturalist, familiar with the interpretation of forms, biological affinities with distant or near-by lands, and thereby shed side-lights, frequently instructive, upon the migrations of plants and animals. And they are, or have been, in themselves experimental stations, where the theories of specific change or specific origin may find partial endorsement or helpful refutation.

Long before Wallace wrote his "Island Life," they had attracted observers, and the unity with, or the diversity from, adjoining islands or contiguous mainlands, of their flora and fauna furnished abundant proofs of their ancient separation or their recent union with both.

An island, too, has its limits so irrevocably fixed, becomes, from its isolation, such a definite tract, that its study has the economical value of concentration and persistency. And this advantage obviously reaches phenomenal value, the more remote the island is from any other, because then its peculiarities teach the naturalist lessons in the origin of living species, or supply the geologist with new types of terrestrial architecture.

It was long ago pointed out that

if we visit the great islands of the globe, we find that they present anomalies in their animal productions, for while some exactly resemble the nearest continents, others are widely different. Thus the quadrupeds, birds and insects of Borneo

correspond very closely to those of the Asiatic continent, while those of Madagascar are extremely unlike the African forms, although the distance from the continent is less in the latter case than in the former. And if we compare the three great islands, Sumatra, Borneo and Celebes, lying, as it were, side by side, in the same ocean—we find that the former two, although farthest apart, have almost identical productions, while the latter two, though closer together, are more unlike than Britain and Japan, situated in different oceans and separated by the largest of the great continents (Wallace).

These unexpected results warranted the inference that the contrasted areas, despite their nearness to each other, had, for long periods, been severed, and that those, on the other hand, which were widely sundered had been at some time, in some way, united by intermediate connecting land surfaces.

Iceland is an island of most respectable proportions—a little larger than Ireland; it occupies a position on the earth's surface especially interesting from its arctic relations, it furnishes sensational contrasts by reason of the union, within its limits, of the opposed empires of frost and fire; its plant life has European affinities; its insect life is restricted, but also European; its bird life has a European expression, but pertains also to the circumpolar distribution of identical birds in both hemispheres; its geological history is recent and startling, and its scenery strange and magnificent. It is, therefore, not surprising that it attracts scientific and adventuresome visitors, though it seems to the writer that these would naturally increase if, at least in America, this island received some sort of popular elucidation. Such is the purpose of this article.

Besides the especial wonders of its bold and frowning cliffs, its ice-buried mountains and its foaming and tempestuous rivers, Iceland for centuries has been the home of romance. Baring Gould was perhaps the first modern English writer who appreciated and adequately described the bewildering impressions made by Iceland upon a visitor, though he failed to see its most marvelous aspects, and he pays his tribute of praise very well indeed. It was our own Bayard Taylor who, somewhat later, on the pages of the *New York Tribune*, remarked,

not that there is no interest in Iceland itself. On the contrary, the handful of old Scandinavians there preserve for the scholars of our day a philological and historical interest, such as no equal number of men have ever achieved in the annals of the world. A thousand years ago they cut loose from Europe and carried the most virile elements of its past almost out of reach of later changes. But Iceland is so remote from us, in an intellectual as well as a material sense, that any satisfactory knowledge of it requires a special appropriation of time and study.

The easier and more common way to Iceland, the one taken by the writer, is by the United Steamship Co.'s steamers (the Danish mail line), which leave Copenhagen, at frequent intervals during the sum-

mer, stop at Leith, the port of Edinburgh, and then variously steam northward to Thorshavn on the Faroe Islands, and thence to Reykjavik, the capital of Iceland at its southwestern headland, or turn to the eastern coast of Iceland at once, and circuitously, landing at the settlements and towns in the fiord valleys, circumnavigate it, finally disembarking the traveler at Reykjavik.

It was in the latter way that the writer determined to gain some insight into the coastal features of Iceland before he made a short but instructive dash into the interior, from Reykjavik, using for that purpose the indispensable Iceland pony. This is that most conscientious, affectionate and captivating little beast, whose docility and pliability—when knowingly handled—have made him the Icelander's constant companion, his only available substitute for the trolley and the railroad.

The omniscient Cooke has not been unmindful of the prospects of profit from the chance tourist drawn to the fabled shores of Iceland, and has already provided excursion tickets from New York to Iceland with accompanying arrangements for the equipment and conduct of parties into the interior. In this way the *soi-disant* explorer may most conveniently form his plans for this unusual outing. Less dependent and more ambitious men arrange with leading guides at Reykjavik for the despatch of men and horses and provisions to the east coast from Reykjavik. They meet these expeditions at some of the settlements, and traverse the island from east to west, fording the rivers, hunting over the moors, fishing in the lakes and streams, possibly skirting the huge icefields, and reaching Reykjavik in time for the returning steamers in September. A third and most important group of visitors are professional men, who also take out considerable equipment, in which clinometers, barometers, thermometers, hammers and collecting boxes and bags replace the gun and rod.

Amongst the latter has been Professor Thorold Thoroddsen, of the University of Copenhagen, who for thirty years has made a laborious inspection of the natural features of Iceland, visiting under circumstances of danger and extreme discomfort, its most inaccessible localities, and Professor K. Keilhack, the German naturalist, whose articles both in geology and in natural history have aided greatly in the scientific interpretation of this domain of wonders, while Professor Slater, of the British Museum, has only recently contributed, in his admirable account of the birds of Iceland, the garnered results of his travel and observation to the growing library of *Icelandica*. In this connection I should mention the capital "*Flora Icelandica*," of Stefan Stefansson, which has recently appeared, and wherein the botany of Iceland receives an extended and systematic treatment.

The approach to Iceland was made in an impervious and haunting

fog which later became confounded with, and imperfectly dissipated by, torrents of rain. It was a disappointing reception, and all the more vexatious because at Faskrudsfjord, the first stopping-place, occasional raisings of the curtain gave spectral glimpses of vast snowy peaks accumulated in unseen grandeur behind the rolling folds of the mist. It was in a measure a compensation for their obscuration that plentiful showers seamed the steep cañon walls of the inlet with plunging silver cataracts. These developed with instantaneous rapidity, leaping down over the basaltic cliffs in innumerable threads.

A word descriptive of the physical configuration of Iceland will make more clear the outline and incidents of the trip about the island. Iceland has in general a subelliptical shape with its longer axis lying northeast and southwest. This approximate form is extended into a sort of lateral exerescence or finger-formed expansion at the northwest margin, in a deeply dissected peninsula, which lies between the Breitfjord and the bay of Hunafloi (see map).

The island is fringed on its eastern, northern and western shores by a continuous succession of inlets, bays, fjord-like arms, which often subdivide and branch at their heads into smaller crevices and communicate with lowlands or valleys leading back into the hills and the interior. The southern shore offers a considerable contrast to this fimbriation of its other coasts, and while it is assumed by Thoroddsen that the southern shore was at one time indented by similar inlets, to-day it presents an *entire* outline which represents broad margins of sand, flows of mud and detrital deposits, scored by glacial streams, and punctuated by lakes or lagoons, in other words, a fjorded area blocked and filled up by later blankets, and upthrown banks and plugs of sand from the sea, or by the fluvial washings from the higher country, and the past deluges of sediments from the melting glaciers.

The trip about the island is made up of entrances into these fjords, and of skirting the coast, which presents a series of superb pictures, while the occasional stops permit transient glimpses of the life and industry of the people. Our company, on the staunch little craft *Vesta*, conducted on its devious ways by the bluff and able seaman, Captain Braun, was one of diversified elements and entertaining contrasts. A little group of French wanderers (among them, the daughter of the great student of hypnotism, Dr. Charcot, and Professor Gourdon, geologist of the French Antarctic Expedition) imparted a continental elegance to our homely equipage, the Englishmen and one most amiable and companionable Scotchman, furnished the necessary insular sobriety and steadiness, a versatile and courteous German trader aided us at all points with explanations and directions, two English ladies revealed unexpected liveliness and powers of amusing

comment, and a lovely Icelandic maiden, returning to her home, after a three years' absence in Denmark, provided a becoming touch of sweetness and roguish charm. The crew and officers were obliging and considerate, and some interesting Danes and Icelandic students completed our passenger list, which, however, expanded into unmanageable proportions, as from place to place, on our approach to Reykjavik, new applicants for berths and table-room made their appearance.

I have hinted at our unsatisfactory reception at Faskrudsfjord. In a measure this disappointment was forgotten in the sense of sudden novelty the surprising pictures before us aroused. The cloud-draped mysteries of the Faroe Islands had awakened expectations certainly, but, to the writer, at least, the scene unfolded as the steamer approached the shores of Iceland, and entered the first deep incision in its rocky sides, was of an unrecalled strangeness and incomparable with anything he had seen before.

It was at four o'clock on the afternoon of August 3 that we came in sight of Iceland after passing, many miles before, a low rocky island engulfed in the swinging curtains of the fog, and though the picture was veiled in mist it excited expectation. The island hid itself from the first vulgar stare of curiosity and drew around it its protecting veils of cloud. First indefinite outlines appeared, one range or hill behind the other, with ill-defined and evanescent openings, then steep bold profiles of dipping beds—the lava flows, apparently successive and gently elevated in mass—and then the coast came more distinctly in view with a green veil of vegetation covering but scantily the broad deep and long talus of debris and disintegrating stone, upon which long threads of falling water in silver lines were easily discerned, even to their moving particles.

On, with the palisades, perhaps 1,000 to 1,500 feet in height, revealed and then hidden in alternate intervals, in the drifting mist and hurtling rain. Finally, we turned into Faskrudsfjord, and slowly steaming up over the quiet water we saw on either side the high 'skrees' gushing with water; long sinuous lines of water, often where they fell over short escarpments forming brief waterfalls, and elsewhere broken successional cataracts, until the cliff-sides were fairly fringed and embroidered with argent lace, a really wonderful picture.

At the very head of the bay rose more lofty mountains, one behind another, in solemn vagueness, dashed with broad snow patches, intermittently seen, and always streaked with streams. These fugitive glimpses were tantalizing enough. They were also only partial. The curtains of fog, moving fretfully over the landscape, suggested, as we watched their grudging revelations, many concealed peaks.

On the north shore was a settlement of some sixty houses, with a hospital of the French government for French fishermen and sailors,

and another of the Catholic church. We had seen farther out, towards the sea, little farms with small enclosures framed in stone walls, or with turf walls, consisting of grass fields. The cemetery, near at hand, was a quaint silent bleak spot on the edge of the water, with a fence round it, and bristling with wooden crosses. Some small houses were covered with sod and had green roofs. It was all singularly new and exhilarating. The storm refused to lift nor did the rain desist. It came down in deluges, and the streams leaped more impetuously, and the cataracts became swollen and vociferous, until a murmurous roar arose from the shores around us. The fog hung low on the mountain-sides, and, as if from their drenched edges, streams poured over the sheer slopes.

Then out to sea over rolling surges and tilting swells. The palisades of rock continued, with higher peaks at intervals, and then we entered Eskifjord, where the renowned Iceland spar is obtained, those pellucid cakes of carbonate of lime, from which the optician adroitly cuts the Nicol prisms for microscopes, which again in the hands of the lithologist reveal the structure and the composition of rocks. I went ashore at night in a pelting rain, and after some miserable wandering over the shore path, by the little huts and houses, through plentiful pools of water, entered a comfortable ware room where the precious material, weighed in small cleavage rhombs, could be secured. Eighty cents was paid for one of these specimens. New quarries are reported from the south side of the island.

This beautifully clear phase of the carbonate of lime forcibly recalled analogous developments in the palisades—the trap formation—of New Jersey at home. Iceland, indeed, throughout most of its northern section is a vast basaltic terrain, a land built up of igneous effusions exuded from opening crevices in the earth's crust in viscous semi-slaggy flows, and piled upon each other, possibly beneath the surface of the sea. Elevation succeeded, and these accumulations rose gently, with only unimportant dislocations upward. They were built upon a submarine spur, probably extending interruptedly from Norway with a southern arm towards Scotland, the whole hidden chain surrounding a deep northern area which, at some time, when its now submerged barriers were exposed, may have formed a landlocked ocean, framed indeed on its southern margin by a *dry* north sea.

The igneous material involved in this construction of Iceland, though analogous to the New Jersey palisades, began its constructive work much later in geological time. The New Jersey palisades date from the Jura-triassic period, those of Iceland are referred to the middle, at the earliest, of the Tertiary age, though continuously since that time through preglacial, glacial and postglacial time, up to the present era, volcanic outbursts and new accessions, whether of lava



NORDFIORD. Skirt of fog on mountain.

or ashes, have increased its size. But, in the sequence of igneous additions, the character of the rocks has changed, and differs strikingly from the original basement basaltic flows. Thus have the fires of earth raised a monument above the tides of the Atlantic.

No sooner had this architectural wonder been raised by Pluto, than Neptune and Jupiter Pluvius conceived its destruction, and their machinations for its overthrow were inconsiderately helped by their subterranean brother. Earthquakes have doubtless altered and reduced its size, detaching or sinking broad patches or morsels of its periphery. We can imagine, to continue our simile, that Pluto, groaning and agitated over the envious assaults of the upper gods, helped to knock out some of the underpinning of his own creation.

But in their process of reduction the air deities have made Iceland most attractive, wonderfully picturesque; they have cut out its deep fiords, furrowed its cliffs, dug grottoes in its stony walls, put pinnacles and minarets along its sky-lines; they have led valleys, green with pasture and splashed with the color of flowers, down to its wave-strewn lips; they have dropped island pearls around its coasts; they have



CUPOLA-TOPPED MOUNTAIN IN SEYDISFIORD.

planted sapphire brooches upon its bosom in the great interior lakes, and spread over its shoulders the braided tresses of a hundred rivers; they have covered its mountains with diamond shields, and in their ruthless attack converted mountainous elevation into ranks of serried hills repeating the ruby pallors of the midnight sun.

Again we left Eskifiord and in our exit reviewed, as before, the steep rocky walls of the fiord, the dipping stratification, the streaming rills. Minareted summits like low parapets fenced the tops of the palisades. We passed a whale fishery with an eviscerated and skinned carcass on the dock before it, and then out over rolling waves with mist and rain, and later entered our third fiord—Nordfiord. The stormy weather was slowly succumbing to more favorable influences, and when at last the vapors rolled up into clouds we found ourselves in a deep strait between lofty walls of rock shooting out of sweeping slopes and undulating upland, which seemed in that northern sunlight, and beneath those frowning sentinels, so desolate, their austerity emphasized by a few isolated farms. One could imagine the wintry terrors of those lonely homes.



TURF-COVERED HOUSE AT SEYDISFIORD.

The streams were still running and the terraced weathering of the rocks was well shown. Towards the ocean a range of high peaks was seen, which formed the southern boundary of another fiord, twinned with the one we were in, and far back beyond the head of the fiord rose immense backs of mountains, spotted with snow. We passed again out to sea upon a rolling swell, into splendid clear water, and skirted the superb front of receding basaltic steps, each one of which was a separate flow, and where as many stages as twenty or forty were counted in their structure, showing bold stepped profiles.

At the summits of these amazing walls, erosion and weathering seemed to have worked with greater activity, forming deep alcoves, sweeping recesses, and then cirques were seen between the lofty divisional massifs. Water-ways or shallow fiords divided this remarkable face of rock into component fractions, and as the last one appeared—sentinel to the beautiful Seydisfiord—green slopes encircled its formidable precipices holding lonely farms, and a spouting waterfall sprang outward from its riven side. We were at Seydisfiord.

The village of Seydisfiord was perhaps the first which breathed a



PONIES AT SEYDISFIORD.

very real air of comfort. It had a hospitable look. A pleasant post-office, a well-furnished apothecary shop—in which minerals and curiosities mingled with drugs and extracts—a candy store, a village hotel, and trailing groups of pretty children and young girls were not wanting to impress the senses with an unusual impression of creature and home blessings.

The important human aggregates in Iceland are along its shores. The population of the interior forms minute hamlets, or is strung out into attenuated lines of farms, many miles apart. The shore settlements meet the outside world, the wear and tear of life is greater, and exchange of material in business ways more active. Here education and culture extend themselves more quickly, and world-ideas receive acceptance and circulation. The farmers struggle with the drudgery of harvesting the hay, breeding and raising sheep and cows, making butter and repairing and making implements and houses. They become a conservative and backward element, and miss the reaction with foreign ships and visitors, and the political spirit is with them more dormant and inactive. In the shore-villages, adven-



FALLS ON THE FIORDURAU ON SEYDISFIORD.

ture, accidents, money-making and dissipation help the movement of life, the attrition is more constant between men, and they emerge more quickly from immature and limiting prepossessions. The farmer is resourceful, brave and wise in his arts, but it seems certain that information and direction would increase his earnings and widen his activity. Banks and means of loaning money have appeared in Iceland, and with them come enterprise, risks and speculation, and attendant amelioration of conditions, with new outlooks and ambitions.

The village of Seydisfiord wanders attractively around the head of the bay, which receives the rushing waters of the Fiordurau (*the river of the fiord*), and our alert tourists assembled, early on the morning of our arrival, a group of ponies—fat and vigorous, with charming heads and exuberant manes—for an excursion up the valley of this river. The objective motive was a series of waterfalls, one behind the other, which were to be seen up the valley. These falls were the physical symptoms of the recession of the stream itself, as it wore its way backward. The rocks about them were much sculptured and worn, and offered an entertaining geological riddle as to whether the lower falls



FALLS ON THE FIORDURAU, SEYDISFIORD.

might not overtake the higher ones, or whether the series represented the scattered parts of a former fall of a height equal to the added heights of each. In the former case, the process would bring about in centuries of time a resultant lofty fall, and in the latter case their separation would probably widen as the river at the upper falls wore its way backward more and more rapidly, and left in its retreat its lagging lower companions.

Some of us rejected the assistance of the ponies, and walked. We made our way over an evil road, from which we wandered promiscuously in search of the tempting flowers, observing among them the rare *Pinguicula* which looks so like a spurred violet, and which we had taken in Newfoundland. And we ran to and fro avariciously picking up *Habenaria*, *Salix* (the dwarf willow), *Betula*, *Rumex*, *Plantago*, *Armeria*, *Polygonum*, *Gentiana*, *Ranunculus*, *Geranium*, *Parnassia*, *Potentilla*, *Epilobium*, *Papaver*, *Dryas*, *Pyrola* and many others almost forgetting the falls.

Falls (*foss*) are common objects in Iceland. They have a strong family resemblance, except the Gullfoss which is unique: but then the



VIEW GOING OUT OF SEYDISFIORD.

family has a high type of beauty. The wall character of the land, the prevalence of great snow fields, and the deluging rains furnish the two elements for first-class waterfalls, and they are excellent. As we scrambled from one to another on the Fiordurau, they improved in looks, and only the restraining finger of time prevented us from chasing the river to its last cranny of refuge. The view back over the fiord and its fringe of houses was one of great beauty.

Certainly the water present in the landscape was not confined to the river. It generously covered everything. Nothing could have been more opulent than the morasses and upland bogs we waded through, driven to the stress of a short cut by the far away summons of the steamer's whistle. Of course, we reached the steamer an hour before she stirred from the dock, with shoes that would have put a Broadway bootblack into a mania of imprecations. We left Seydisfiord regretfully, and here we bade good-bye to the courteous young Dane who will superintend the submarine cable now laid between Scotland—by way of the Shetland and Faroe islands—and Iceland.

Again out to sea, and again the panorama of sloping and beetling

palisades, of broad embrasures and galleries, dug out by weathering agencies, with the clear aqua-marine waters rolling languidly over jagged barriers of basalt. Vopnafjord seemed flat. It was our next stopping place. The French ladies declared it looked like Brittany and perhaps it did. They ought to know. It was a low shore, rocky, with green uplands and farms, and many threatening reefs. On again in fog with a coast intermittently seen to the left, and at night we passed into the arctic circle, and, as the day dawned over the magic sea, the air became brilliantly clear, the sky serene and cloudless, the waves docile and appeased.

We were far away from the shore. It was the northern edge of Nord Thingeyar Sysla with remote lines of elevation and long horizontal lines like some topographic section. We crossed the broad Axarfjord, on a sea blazing with light, and approached the islands of Minareyjar dancing in mirage, and soon passed Red Hook, carmine with iron secretions oozing from its jointed rocks, and along an old raised beach with enormous moorlands behind it, which a sporting vice-admiral of England declared were full of partridge (*ryper*), and which had a most inviting wild remote loneliness expressed in them.

(To be continued)

THE SACRIFICE OF THE EYES OF SCHOOL CHILDREN

THE HUMAN EYE EVOLVED FOR DISTANT VISION

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IN the evolution of the animal organism the sense of touch has served the purpose of informing the individual of objects with which it came in contact. The sense of taste likewise gave information concerning objects upon contact, but of a more specialized form. The sense of smell and that of hearing gave knowledge of objects in the vicinity and in certain instances of objects in the distance. The sense of sight seems to have been preeminently the sense by means of which the individual was enabled to adjust himself to objects at a distance. The enemy to the leeward might approach noiselessly and so could not be smelt or heard. When knowledge of the approach was revealed by the sense of touch it was too late for escape. The preservation of the individual and of the species thus depended upon the ability to see the enemy in the distance. Inasmuch as the function of the eyes has been to perceive objects at a distance rather than at close range, we are not at all surprised to find that the eyes are well adapted for distant vision, but poorly constructed for close work.

When our eyes are at perfect rest, when all the muscles which control them are relaxed, they are then adjusted for distant vision. When, on the other hand, the ciliary muscles and the muscles which move the eyeballs are at a maximum of contraction, then and then only are the eyes adjusted for close vision. Such a structure was admirably adapted to the needs of the primitive organism. The eyes were the sentinels which must always be on guard and when employed in the appropriate way there was no strain. It was of course essential that the individual should be able at times to see objects close at hand. This could be accomplished by means of contractions of delicate muscles, and as soon as the contractions were relieved the eyes were again adjusted for the more important duty of distant vision.

The strain upon the eyes is in adjusting for objects closer than at about four feet, but for all greater distances there is a minimum of strain. Hence we may speak of all objects as being *distant* which are removed as much as four feet. With this definition of the term *distant* it is evident that distant vision was the most common form of vision for all our ancestors, from the most primitive forms of life

to the most highly civilized races, till the last few centuries. With the invention of writing and then with the invention of the printing-press a new element was introduced, and one evidently not provided for by the process of evolution. The human eye which had been evolved for distant vision is being forced to perform a new part, one for which it had not been evolved, and for which it is poorly adapted. The difficulty is being daily augmented. The invention of printing presses has been followed by an increasing number of books, magazines and daily papers. The rural population has given place to the urban. The long days of manual labor have given way to the eight-hour system with abundant time for reading. Labor-saving devices of all sorts have added to our sedentary habits. All things seem to be conspiring to make us use our eyes more and more for the very thing for which they are the most poorly adapted. It requires no prophet to foresee that such a perversion in the use of an organ will surely result in a great sacrifice of energy, if not of health and of general efficiency.

The Amount of Light required for Reading

The eye has thus far been spoken of as though it consisted merely of delicate muscles, when in reality these are not the most significant part of it. In thinking of the eye we should never disregard the eye-muscles, but primarily the eye is a live camera consisting of a lens, dark box and sensitive plate. The retina in the back part of the eyeball is the sensitive plate and is the most vital part of the eye. It is effected by every ray of light falling upon it. Fortunately it responds to a weak light and still is not injured by a moderately strong one. In speaking of the quantity of light it is well to have a standard. For this purpose the most convenient standard is the amount of light cast by a standard candle upon any point in the horizontal direction one foot from the candle. A light of twice this intensity is spoken of as a two-candle power, a light ten times the first is of course a ten-candle power. The light cast by a candle upon a printed page at a distance of one foot is sufficient for legibility at the normal reading distance. If the light is less than this the retina is not adequately stimulated and the reading is accomplished only after a strain more or less intense. If the light falling upon the page exceeds ten-candle power the stimulation of the retina is so great that it is displeasing to some people and is condemned by our best authorities as injurious to the retina. All are agreed that less than a single candle-power is injurious for reading, and during the present state of our knowledge it is at least safe to avoid an illumination of more than ten-candle power.

The iris may be blue, brown or gray and is that which determines the color of our eyes. It is an adjustable shutter which reflexly regulates the amount of light which enters the eye. In the presence of a

bright light the iris diaphragm contracts, reducing the size of the pupil and cutting out much of the light which would otherwise enter the eye. In the presence of a dull light the pupil enlarges, allowing a great amount of the light, such as that falling upon a book, to enter the eye and to stimulate the retina. The iris is a wonderful device, but can not in diverse illuminations perfectly equalize the amount of light entering the eye. The pupil expands inversely as the square root of the illumination. Thus if the actual illumination of the book increases ten-fold, the amount of light falling upon the retina is increased but little over three-fold. Even a twenty-five candle light sends but five-fold as much light into the eye as a single candle-power. A single candle-power seems sufficient and ten-candle power is not too much. This ability of the retina and of the iris to deal successfully with lights of such different intensities is a most useful and necessary characteristic. Unfortunately, however, the actual diversities of intensities of lights used for reading are far beyond any for which the eye can adapt itself.

Variations in the Amount of Daylight

We are in the habit of thinking of the light received from the sky—the daylight—as almost a fixed quantity during the hours from 9 in the morning till about 4 in the afternoon. The darkness preceding a storm and the occasional dark days are of course not forgotten, but, in general, daylight for the hours mentioned is thought of as at least fairly constant. To test this point observations were made at 9 A.M., 12:30 P.M., and 4:30 P.M., daily for five and one half days a week for 22 months. These tests were made in the Chicago laboratory of the American Luxfer Prism Co., and under direction of Professor Olin H. Basquin, of the Department of Physics of Northwestern University. Inasmuch as the amount of sunshine and general illumination in Chicago is almost exactly the average for the United States, these results may be regarded as typical for the whole country with the exception of such dark cities as Seattle or such light ones as Phoenix. Measurements were made of the amount of light coming through a square foot of clear glass placed horizontally in the roof of the observation building. The illuminometer was placed so far below the opening in the ceiling that the direct rays of the sun could never reach any part of the recording apparatus. The light thus measured was diffuse daylight received from the zenith of the sky. Taking the average illumination for the 22 months at 12:30 as the standard, it was found that the illumination at 9 A.M. was but 67 per cent. as great as that of mid-day. Again the illumination at 4:30 P.M. was but 27 per cent. as great as that at 12:30. Expressed in other terms, we see that the available light at 4:30 is approximately but one fourth that of noon and the light at 9 o'clock but two thirds that of noon. These

figures are the average for the school days of 22 months in one city, and although observations for a longer period and in other cities might change the results somewhat, it is safe to assume that our figures are not far from the actual conditions in a majority of our school rooms in the United States. In general a room which is barely adequately lighted at 12:30 will be 33 per cent. under-illuminated at 9 o'clock, and at 4 o'clock its illumination will be but 27 per cent. of the necessary amount.

Our difficulties are further complicated by the fact that the variations in illumination of daylight are as great between the months of the school year as between the hours of the school day. The illumination is best in the months of June, July, August and September. Then follows in order May, April, March, October, February, November, January and lastly December. Comparing the illumination of the four bright months (June, July, August and September) with the four dark months (November, December, January and February) we find that for the 22 months observed the illumination of the dark months is but 28 per cent. of that of the bright ones. This figure is found by averaging the three daily readings for each day for all the months concerned. December, the darkest month has but 18 per cent. as great illumination as June, the brightest month.

When to these variations as between months or seasons we add the variations between mid-day and morning and evening, the results are most astounding. The light at noonday in June averages almost ten-fold as much as that at 9 A.M. in December. If it is injurious to read with a light less than one or more than ten-candle power, a schoolroom that furnishes this maximum in June will be reduced to the minimum in December mornings and evenings on average days. Such deviations in the external source of light put most restricting conditions upon school architecture. How have we met the conditions and how might we construct our schoolrooms to meet the situation satisfactorily?

Rules for Lighting a Schoolroom

In our climate it is almost impossible to over-light a school room if the two following conditions are observed: (1) Never allow the direct rays of the sun to fall upon any surface within the field of vision of any pupil. (2) Avoid all glossy or shiny surfaces which reflect the light directly into the eyes of the pupils. A dead white surface is not injurious, while a darker surface may be shiny and hence injurious.

For securing adequate light the following rules are important: (1) The window space should be as much as one fifth of the total floor space, and the height of the window two thirds of the width of the room. (2) The walls, ceiling, woodwork, furniture, etc., should be a color which reflects a large amount of well-diffused light. Perhaps

the best colors for this purpose, in the order of their efficiency, are white, light yellow, light gray, light green, light blue and light pink. (3) The schoolroom should be narrow and the windows facing an unobstructed area, so that from any seat in the room a large amount of sky is visible. (4) The windows should be provided with white Holland screens, or others of a similar sort, which obstruct the direct rays of the sun, but which, when drawn down, emit into the room a maximum of diffused light. (5) There should be at hand light colored curtains which may be used to cover up all blackboards as soon as the darker parts of the room are inadequately lighted.

It is apparent to all that the construction of our school rooms has not conformed to these five simple rules. There are many rooms in which the window space is one fifth of the floor space, but certainly not a majority of all schoolrooms in America. The second rule, concerning the reflecting surfaces within the schoolroom, is broken by the extensive surfaces of black-boards and by the dingy color of the walls. Walls soon fade and become dirty and need frequent attention to keep their reflecting power approximately at its maximum. The third rule is broken by constructing rooms so large that they will accommodate fifty pupils, and by placing school buildings too close to adjoining buildings. The fourth rule is broken by the use of opaque shades which, when drawn to escape the brilliancy of the sun, leave the room darker than it would otherwise be on a dark and cloudy day. Because of this fact the schoolrooms with a southern exposure are perhaps our most poorly lighted rooms. The fifth rule, concerning the use of white screens for the black-boards, is never observed and to many may seem insignificant. The justification of the rule is found in the following facts.

Dark Corners in Schoolrooms

The ordinary school room has the light from one side. The five rows of desks are so arranged that one row is next to the windows and the last row next to the black-board on the side of the room opposite the windows. It is well known that the desks next to the black-board and farthest from the windows receive less light than the desks next to the windows. That the difference between the first and fifth rows is great enough to occasion any alarm seems not to have been suspected. In the ordinary schoolroom the light reflected from the pupil's book on the first row is eight times as great as the light reflected from the book of the pupil who is so unfortunate as to sit in the row next to the black-board. The decrease of the light as the distance from the window increases is different in each room. The law of the square of the distance is not even approximately correct but it is safe to say that in the great majority of school rooms in the United States the row of desks next to the windows has many-fold more light than the rows next to the black-boards. Professor Basquin and I tested school rooms

having windows on but one side. In these rooms the variation between the first and fifth rows was from seven-fold to ten-fold. By the introduction of screens over the black-boards in the same rooms, the light at the darkest seat was increased as much as 50 per cent. That an increase of 50 per cent. in the light in the dark corners of our school rooms is important is apparent to all. Furthermore, this result can be secured with little or no cost. Most schools possess white screens, light-colored advertising maps, charts printed on white paper, etc. They may be used to cover the black-boards and when thus used they will reflect the light to the very parts of the rooms which need it most.

Because of the lack of attention which is paid to the light actually present in the schoolroom, and because of the great difficulty in adjusting our windows and shades to the varying intensities of the external source of light, it is not surprising that we should find in our schoolrooms conditions of light so bad that during many hours and days the reading of ordinary printed matter without undue strain upon the eyes is impossible.

Unwise Demands made upon the Eyes of Young Children

Until within a very few decades reading was taught by a slow and cumbersome method. The effort of reading was so great that few children enjoyed the reading of a book until after they had completed the third school year. Interesting books for children were few in number and not available for the vast majority of them. To-day this is all changed. Our methods of teaching reading are so improved that before the child has been in school a full year he begins to read books at home for his own pleasure. Our printing presses are teeming with children's books. Andrew Carnegie, or rather the movement which he so ably supports, has filled city and country with free books available for even the youngest. During the last twelve months I have tested the eyes of some 700 children. I have asked of each child an estimate of the number of books read in the preceding 12 months. One room of 31 pupils for the 12 months preceding the middle of the second school year, gave the following figures. The average number of books read by each pupil was 22. Some had read but few, while others had read many more than 22. One half of the pupils had read 20 books or more. It should be observed that this record of the number of books covers the period from the middle of the first school year to the middle of the second school year. After the second school year many pupils read regularly a book a week. In several of the grade rooms tested, the pupils of the room read on the average as many as 50 books a year. In the first three years after reaching the legal school age not a few pupils in our best city schools read 100 books. This figure is certainly far above the average, but there is a tendency

to increase the number of books read during these first three years of school. We should but deprecate the tendency and do all we can to stop it. During these three years the pupils are growing faster than during the following years. At this time there is a decrease in the nervous energy of the child. In recent studies of the order of development of motor adjustments and coordinations, it has been found that the individual first acquires control over the larger muscles and later over the finer ones. The normal activity of the child exercises mainly the larger muscles. The plays of children give the widest scope to the exercises of such muscles. The coarser movements are most predominant while the finer adjustments and the use of the smaller muscles are of secondary importance.

By our improved forms of modern education all this is changed. We put the six-year-old child to the task of reading and writing. These acts involve the use of the smaller muscles of the organism and are dependent upon more exact control of these muscles than any other act the individual is ever likely to be called upon to execute in later life. If an adult is out of practise in the use of the pen, a single hour's work is sufficient to exhaust the hand. The extreme exertion which the child puts forth to guide the pen or to follow line upon line with the eyes is so far in excess of the amount of energy required by an adult that we are not in a position to appreciate the severity of the child's task. Children upon entering school have better control of movements involving the whole arm and the wrist than of those involving the wrist and fingers. The muscular control of the eyes is adequate for all free movements of the eyes, but not sufficient to warrant the finer adjustments of continuous reading. The loss of nervous energy, necessitated by reading and writing, at the ages of from five to eight years is an unwarranted drain upon the health of the child. At this age the child needs free and vigorous movements rather than the constrained and finer ones required in reading and writing. At a later age the control over the finer muscles is adequate for the task, but in this age of rush we are crowding our little ones and inverting the order of nature. Furthermore, the tissues of the globes of the eyes are still soft and the strain of the ciliary and other eye muscles is likely to cause short-sightedness by increasing the anterior-posterior axis of the eyeballs. If the child's eyes do thus lengthen under the excessive strain, the eyes are not only weakened for vision, but they become diseased organs.

We have thus far attempted to establish the following four propositions. (1) The human eye was evolved for distant vision and the perversion incident to reading and writing would lead us to expect some great injury to the organism. (2) Although the eye may easily adjust itself to a light changing from one- to ten-candle power, the diversities of daylight during the hours of the school day and

the months of the school year are so great that the minimum and maximum extremes are frequently exceeded. (3) The necessary rules for lighting buildings are not adhered to, thus placing an unnecessary strain upon the eyes of all attempting to read and write. (4) There is a growing tendency to use the eyes at a period of life which is in every way ill fitted to the task. If these four propositions have been established, and if the pessimistic forebodings are justified, then investigations of the eyes should discover a general destruction of the eyes of civilized countries and an increasing number of eyes injured during the age of from 6 to 9.

Investigating the Eyes of School Children.

Systematic investigations of eyes upon a wide scale were not begun till 1865. At that date Dr. Herman Cohn commenced his investigations of the eyes of school children in Breslau. After having examined ten thousand children, he summarized his results as follows:

Short-sightedness hardly exists in the village schools: the number of cases increases steadily with the increasing demands which the schools make upon the eyes, and reaches the highest point in the gymnasia.

The number of short-sighted scholars rises regularly from the lowest to the highest classes in all institutions.

The average degree of myopia increases from class to class, that is, the short-sighted become more so.

The circular of information of the United States Bureau of Information, No. 6, 1881, in speaking of the many investigations which had been made in this and other countries said:

All, without a single exception, prove beyond a doubt that near-sightedness, beginning, perhaps, at nothing in the lower classes in the school and first year of school life, steadily increases from class to class in the school until in the highest grades or in the last years of school attendance it has actually developed itself in as many as 60 or 70 per cent. of all the pupils.

In all these tests children were not regarded as near-sighted unless their visual acuity in one or both eyes was but two thirds of normal vision or less. Think of the significance of these statements which are entirely authoritative. Pupils entering our schools come to us with good eyes, but if they stay with us till the end of the course, 60 to 70 per cent. of them will leave us with but two thirds normal visual acuity or less. Most of this loss of vision is caused directly by the strain put upon the eyes in reading, writing and drawing.

The Sacrifices caused by Premature Strain

The picture drawn by the investigators during the two decades following 1865 was dark indeed. The only ray of hope was found in the fact that the destruction of the eyes did not begin during the first few years of school, so that pupils dropping out before the eighth

or tenth year would probably escape with good eyes. Thus Cohn found that in the case of pupils $8\frac{1}{2}$ years old there were but 5 per cent. myopic, while of the pupils remaining the full 14 years, 63.6 per cent. were myopic. Investigations of the pupils of other cities of Germany resulted in similar findings. Investigations in America were not so numerous as those in Germany, but in general the results were the same until recent years.

Investigations carried on in Worcester, Massachusetts, in 1891, showed that in the second and third grades from 50 to 60 per cent. of the pupils possessed less than normal visual acuity. Investigations upon over 3,700 pupils of the Chicago public schools, in 1899, showed that the maximum of defective eyes was reached with pupils 9 years old. No one seems to have remarked upon this change in the grade at which the maximum destruction of the eyes is found. In fact the results seemed to have been looked upon as rather accidental and of no special significance.

Some months ago I asked myself these two questions. Is the maximum destruction of the eyes of the school children reached earlier than formerly? Secondly, if such is the case, what is the cause of it? In attempting to answer these questions I have tried to learn what recent investigators have found concerning eyes, and I have attempted personally to examine the eyes of children in schools which were significant. The data which I have secured lead me to conclude that the excessive destruction of the eyes begins several years earlier than was formerly the case in America, and earlier than is still the case in Germany and other foreign countries. As to the cause of the early injury of the eyes the results of my investigations are most significant. The highest per cent. of defective visual acuity I have thus far discovered was found in a room in which the pupils had been in school but $1\frac{1}{2}$ years. This is the room referred to above in which the average number of books read by each pupil during the preceding 12 months was 22. It may not surprise you when I tell you that 84 per cent. of these little innocents had defective vision. The school-room in which they were seated was unusually well provided with windows and had a south exposure. Unfortunately their teacher preferred a rather dimly-lighted room and made generous use of opaque shades with which the windows were provided. The light by which the pupils read in school was in most cases certainly better than the light which they had for their reading of books at home. Some of these children in their childish ignorance took books to bed with them, and upon awakening in the morning read before breakfast. It is probable that in most cases the children at home read during the evening twilight till it was too dark to tell one word from another. Then they would retire to some dark corner of a dimly lighted room and continue the reading till supper time or bed time. Young chil-

dren have no regard for their eyes and parents are not likely to interfere with them as long as they are quiet.

My query as to the cause of the early destruction of the eyes is being answered by my investigations. It seems to be simply because our infants are reading more books than formerly, both in and out of school. In Germany the instruction during the first few years of school life is largely oral and at home the children do not read so much as our children. Furthermore, our children are to-day much better taught than three decades ago, and they read much more than formerly during the tender years of from 6 to 9.

The pessimistic forebodings expressed in the first part of this article are more than justified by the figures just presented. The eyes of our school children are being destroyed, and worse than that, the destruction is now taking place at the age of from 7 to 9 years, which makes the matter so serious that we should bestir ourselves to lessen the evil as far as possible. In the palmy days of Greece the Athenian boy was not taught to read till he was ten years old. By our modern improved form of education we injure the eyes of our children so that one half of them have defective vision before the age at which the Greek boy learned his alphabet.

The gravity of the situation is so great that I venture to offer in conclusion the following suggestions:

1. We should recognize the fact that human eyes are ill adapted for reading, writing and drawing for a long period at a time.
2. We should recognize the fact that the normal daily deviation of daylight is so great that any method of adjusting the windows shades from mere habit is inadequate.
3. In constructing school houses the window space should be as large as that described above.
4. The interior walls and ceilings should be light.
5. The amount of sky visible from each seat should be large.
6. The windows should be provided with white Holland screens or their equivalents.
7. Every schoolroom should be provided with light shades and they should be placed over the blackboards as soon as there are dark corners in the room.
8. School children's eyes should be tested annually and parents notified that an oculist should be employed in the case of all defective eyes.
9. Children should not be taught even the elements of reading or writing during the first year of school. For the ordinary reading and writing should be substituted more oral instruction in language, number work, nature study, history, singing, physical training, play and other forms of training suited to the needs of the pupil.

NOTES ON THE DEVELOPMENT OF TELEPHONE SERVICE

BY FRED DELAND

PITTSBURGH, PA.

XV. FINANCIAL AND TELEPHONIC CONDITIONS IN 1884

IN 1884 the farmers in the United States harvested crops of wheat, corn and oats greater than in any previous year, while the amount of cotton raised by southern planters had been only slightly exceeded in two previous years. It should have been a good year for legitimate enterprises; but it proved an unfortunate period for many. The average export value of wheat was 20 cents a bushel less than the previous year, while the yearly range in the price of wheat in the Chicago market was 96 cents in February and 69½ cents in December. In 1883 wheat had ranged from 90 to 113; in 1882 from 91 to 140 and in 1881 from 95 to 143 cents a bushel. Thus the aggregate value of the wheat exported in 1884 was forty-six millions of dollars less than in 1882.

In January, 1884, came the suspension of the banking house of a well-known financier and also of the business of a leading broker. Following these failures a dreary dullness pervaded financial circles while a dread expectancy of further monetary troubles prevailed in all lines of industry, limiting outputs to the minimum required to meet immediate demands. Then came the eventful month of May, bringing to light the notorious wrecking of the Marine Bank, the failure of Grant & Ward, the suspension of several very prominent banking and brokerage firms and of many small ones.

As a result of the financial failures occurring on two days only, May 14 and 15, the market value of good securities depreciated over \$240,000,000, a slump having a far-reaching effect many times greater than a depreciation of like amount would now have. Eleven national banks and more than a hundred private banks and banking concerns suspended payment during the year, while the total number of failures throughout the United States during 1884 was 10,968, with aggregate liabilities of \$226,343,427. That is, nearly eleven thousand business houses were unable to meet monetary obligations in full, while more than ten times that number probably failed to attain to any measure of success; in other words, either went out of business for lack of funds to continue or because the future gave no promise of success. Then the net earnings of all railroads fell off about 9 per cent., while the

construction of new railroad lines practically ceased, less than one fifth the amount being expended for this purpose in 1884, that was expended in 1882. The bank clearances, which had exceeded forty billions of dollars in 1883, fell to twenty-four billions in 1884, and, as a distressing industrial depression prevailed in several foreign countries, there was only a slight export demand for our products.

Quite naturally all these grave disturbances in financial, industrial and commercial circles seriously affected the growth of the telephone industry. Thousands of subscribers were compelled to dispense with the telephone through inability to pay for its use, or by reason of the closing of places of business, while hundreds who had expected to subscribe were compelled to postpone the adoption of this serviceable utility. Nevertheless, nearly all the larger exchanges reported a moderate growth, and the net gain in subscribers reported by all the Bell companies was 11,222 for the year, making a net increase of 9 per cent., a remarkable growth considering the times and conditions. The gross earnings of all the licensee companies in 1884 exceeded \$9,500,000, or 18 per cent. on a total capitalization of \$53,000,000, not including the capitalization of the parent company, which was \$9,602,000.

On January 1, 1884, there were 1,325 Bell exchanges in operation. During the year 1884 there were 61 new Bell exchanges opened, which, added to the 1,325 exchanges in operation, should have made a total of 1,386 when the year closed. But of 133 small exchanges, "kitten exchanges," as they were called, that had been absorbed in the consolidation of local companies, 63 were converted by the new owners into toll stations, while 70 were closed for the time being, owing to an almost total lack of support. Thus there were only 1,253 exchanges in operation on December 31, 1884, or 72 less than a year previous. Referring to these exchanges, the parent company stated in its annual report:

As a rule, all the larger exchanges have had a steady growth, and there seems no reason to doubt that this will continue for some time to come. On the other hand, there is a pause in building exchanges in small places, and some 78 of those already started have been for the present given up, while 61 new ones have been established. The establishment of these systems in small towns was probably pushed too rapidly, in view of the stagnation of general business which followed. Many of these now abandoned will be restored upon a revival of business, and others can be put into operation under a system which is being worked out for small exchanges without a central office, and which, if as successful as we hope, will carry the telephone into a large number of towns and villages where it is now impossible to place them upon a paying basis.

In this connection it is interesting to compare the foregoing statistics with the following tabulated statement showing the average

number of subscribers connected with Bell exchanges during the past twenty-five years, and to note the steady increase in growth that is recorded during the past ten years. In 1882, the average number of subscribers connected with Bell exchanges was only 91; in 1906, it was 558, an increase of more than sixfold. This compilation is based on the statistics presented in the annual reports of the parent company, as of December 31 of each year:

Year	Exchanges	Subscribers	Average	Yearly Gain
1906	4,889	2,727,289	558	64
1905	4,532	2,241,367	494	53
1904	4,080	1,799,633	441	33
1903	3,740	1,525,167	408	29
1902	3,375	1,277,983	379	39
1901	3,005	1,020,647	340	51
1900	2,775	800,880	289	28
1899	2,426	632,946	261	43
1898	2,134	465,180	218	22
1897	1,962	384,230	196	15
1896	1,799	325,244	181	6
1895	1,613	281,695	175	6
1894	1,439	243,432	169	1
1893	1,409	237,186	168	-4
1892	1,351	232,140	172	5
1891	1,297	216,017	167	3
1890	1,241	202,931	164	13
1889	1,228	185,003	151	7
1888	1,194	171,454	144	11
1887	1,191	158,712	133	9
1886	1,180	147,068	124	7
1885	1,175	137,750	117	9
1884	1,253	134,847	108	15
1883	1,325	123,625	93	2
1882	1,070	97,728	91	

In 1884, some of the Bell licensee companies gladly furnished periodical reports to the parent company giving detailed explanations as to the method of operation and maintenance, the number of subscribers, calls per subscriber, etc. Other licensee companies objected to any and all parental supervision, and especially to furnishing the monthly reports from which data of a uniform character could be compiled. Then, as many licensees were not under the direct management of the parent company, failure to prepare and transmit the desired reports could only be deplored. Again, some of the newer companies that had been established on a speculative rather than an investment basis objected to the proposed adoption of uniform methods of operation, maintenance and construction, although the economy and advantages in standardization in methods and practise, as well as in construction and equipment, were clearly apparent to the unbiased mind. Nevertheless, the parent company did succeed in securing many statistics that are now invaluable in illustrating the progressive growth

of the telephone movement; and in its annual report for the year 1883 stated that:

With the acquirement of large interests in our licensed companies comes the necessity of more oversight of the business, and, as far as it can be obtained without absolute ownership, an exact comparison of results. The organization of the company should be shaped to meet these requirements, and with proper watchfulness and effort on our part, we may expect steady growth and improvement in the character of our business in all its branches.

The same difficulty in gathering statistics was experienced by the respective secretaries of the National Telephone Exchange Association, and by the committee allotted the work of gathering statistics. At the meeting held at the Continental Hotel, in Philadelphia, in September, 1884, Mr. W. D. Sargent, chairman of the committee on exchange statistics, presented a comprehensive report of great value, and representing an enormous amount of individual work, covering the number of exchanges, of subscribers, circuits, methods, wages, etc. Yet of the 906 exchanges belonging to members of the association, he was only able to secure reports from 210. Single exchanges formed the basis of 200 of these reports and included 30,421 subscribers, or an average of 152 subscribers to each exchange. But 79 of the 200 reported less than 50 subscribers; 49 reported between 50 and 100; 31 between 100 and 200; 14 between 200 and 300, and 10 between 300 and 400.

The editor of the *Electrical World*, in referring to the financial conditions prevailing during 1884, wrote:

Our country, equally with the other parts of the civilized world, has passed through a crisis of depression and distress. Commerce has languished, the busy hum of factories has ceased; costly machinery has rusted in idleness; banks have succumbed to the drain upon their reserves; mines have been shut down, and toilers by the hundreds of thousands have sought in vain for employment at the merest pittance. But amidst all these signs of dull times, and while suffering a natural sympathetic restriction, electrical industries of all kinds have prospered in the main and grown apace. . . . In January, when reports were current of a proposed deal between the Bell and Drawbaugh interests, the price of Bell stock was about 200. Then as the year and the hearing of evidence in behalf of Drawbaugh, in Pennsylvania, progressed, the price fell, until in May, at the time of the panic in Wall Street, it reached 150. That was the turning-point, and it rose gradually until Judge Wallace handed down his decision, when it jumped from 195 to 265.

Referring to the financial condition of the local companies at the close of 1884, the parent Bell company, in its annual report to its fourteen hundred stockholders, said:

Nearly all our licensed companies are in good condition, and many of them continue to pay regular dividends in spite of the general dullness. It has not, however, been a year when new enterprises of any kind could be easily pro-

moted, and in common with other industries, the telephone companies have found it difficult to sell stocks or bonds for their construction purposes. It has been probably as much due to this as to the lessening of the demand for telephone service that our output of instruments has decreased. Most of the companies have met this condition of things by applying their net earnings in part, and in some cases wholly, to their new construction. The result of this conservative policy, although temporarily disappointing to stockholders, has been to materially increase the intrinsic value and earning capacity of the properties, and in view of the importance of an early occupation of the field while numerous infringing claimants were striving to gain a foothold, we have no doubt the policy was the right one. How far it should be continued under the more favorable conditions that now prevail is to be carefully considered by each company.

On December 5, 1884, Judge Wallace delivered his opinion in the Drawbaugh case. In part it reads:

Concededly Bell was an original inventor of the telephone, the principle of which with the essential means for its application, are described in his first patent, and of the improved apparatus described in his second patent. . . . Mr. Cross, an expert, caused apparatus to be made in conformity to the description and to drawings as shown in Figure 7 of the patent, which proved itself to be an operative, practical telephone. Probably the date of his (Bell's) inceptive invention might be carried back to July, 1875, but irrespective of the time of the invention, the justice of his claim to be an original inventor of the telephone must remain unchallenged. It was through him also that the telephone was made known to the scientific public, and thence introduced into commercial use. . . . From 1867, to July, 1873, Drawbaugh was intimately connected with persons composing the Drawbaugh Manufacturing Company, which was engaged in manufacturing devices under Drawbaugh's patents. He was a stockholder and the master mechanic of the company. Among the officers and stockholders were many men of capital and enterprise. There came a time when the managers of the company wanted Drawbaugh to suggest new devices for the company to manufacture. He never suggested the telephone nor attempted to induce the managers of that company to investigate or exhibit his talking machine. A number of the managers and employees of this concern testify that they never heard of the existence of the talking machine during the life of the company. Without attempting to refer to other testimony to the same general effect, what has already been referred to, shows that if Drawbaugh had seriously desired to bring his talking machine into public notice and secure the fruits of his invention, he had ample opportunity to do so. . . . Without regard to other features of the case, it is sufficient to say that the defense is not established so as to remove a fair doubt of its truth, and such doubt is fatal.

LINNÉ AND THE LOVE FOR NATURE.¹

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SPRING, always the delight of the lover and of the poet the world over, becomes more and more so the farther we go into the north. Nowhere are the spring songs so full of feeling as in Scandinavia. When the northern winter, over-dark and over-long, is past; when returning light and warmth inspire sleeping nature with new life; when the blue anemone, close to the fast-retreating snow, looks up into the cheering sun; when the birch puts on its delicate fresh green; when the thrush pours into the fragrant air its love-song, then, as Linné puts it, "love seizes even the plants," and the spirit of spring awakens the heart of man into a new joy. It was when this Swedish spring was at its best that the blomsterkung (king of flowers), Carl von Linné, was born, and in the romantic north, where fancy is still free to roam, it is natural that the good people should imagine some bond between the season and the child. And surely the May child, who in his cradle stopped crying when a flower was placed in his hand, grew up to be a lover of the flowers and of all nature.

This love for nature, which marked the whole life of Linné, was inherited; and he was brought up among the flowers in the garden of Stenbrohult, his father's Småland parsonage. The flowers were his playthings and their names almost the first words on his lips. Once when hardly four years old he followed his father to a lovely äng, or flower-covered meadow, and overheard him telling his friends the name and properties of each of the plants. After that, he never ceased to ask his father for the name of each plant he met. Once, when rebuked for forgetting and asking again in the childish way, he made up his mind to put his whole energy on keeping in memory all that he was told, for he did not wish to miss hearing about the things that were dearest to him.

Linné never forgot the race of peasants and priests from which he rose, nor did he forget the humble flowers of Stenbrohult. Years afterward when at the height of fame, he visited his early home and wrote in his notes, "To the flowers, my childhood's play-brothers of Stenbrohult on the banks of Mökeln, now I bade farewell," and then he goes on to call the plants and the weeds by name.

¹ An address delivered at Augustana College, Rock Island, Illinois, on the occasion of the celebration of the two-hundredth anniversary of the birth of Carl von Linné (Carolus Linnæus).

When the boy came to go to school he cared less for his books than for his flowers. Instead of allowing himself to be put through the educational mill of the times he preferred to roam over the fields and, when there came time for reading, to devour the books that would tell him more about his friends, the plants. He thought his teachers unfeeling and rude, and they thought him stupid. His father and mother, who wanted him to become a pastor, were discouraged and came near making him a cobbler. But the boy was not stupid, nor lazy, nor worthless. All the while, his powers of accurate observation were growing and he was storing up the knowledge that would be useful to him in the life that he was to lead. In time his powers came to be recognized and Dr. Rothman, one of his tutors at the school at Wexiö, more sympathetic than the others, assured the father that of all the scholars studying in Wexiö there was no one that gave as much hope as Carl. Thus the way was opened for him to devote himself to the study of natural science and of medicine, instead of theology, but not until after long family discussions. Once the boy heard his father say, "What one has inclination for, that will he have success in" (*Det man har lust för, det har man lycka till*). The boy asked him if it was really so, for if it was, he could not have success as a pastor, for which he had no inclination. The father suggested how costly his chosen scientific studies would be. The boy replied, "If the proverb has any ground, God will provide the offering. If I have success as I have inclination, so ways-out will not fail me." The father, with tearful eyes, gave his consent: "Then may God grant you success. I shall not force you into that for which you have not inclination." And so the boy set out for the University of Lund, where he won the life-long friendship of Stobæus. Here, and later at the University of Upsala, he read all the books he could find on botany and studied the plants of the gardens as well as of the fields and woods. His knowledge of plants was so unusual that Celsius, who came upon him by chance in the Botanical Garden at Upsala, took him home, and interested himself in the scientific advancement of the student. At the universities Linné put his serious energy on the sciences for which he was fitted, but never did the book learning nor the passion for acquiring knowledge cool his inborn love for the flowers.

If a childhood and youth like Linné's suggests a spring morning, so the passing from that youth into the fullness of life is like the passing into a sunshiny day, a day so beautiful that it never loses the color and the freshness of the dawn. Few lives have been more crowded than Linné's. He had time to study not only his beloved botany, but all the natural sciences, even assaying, and to earn his living as a physician. He had time to go on collecting trips throughout Sweden and parts of Europe; time to identify, name and classify

thousands of plants, insects and animals; time to write ten score scientific books and treatises; time to direct hundreds of students who gathered at Upsala from near and far to be guided by the new organizer of science; and yet in all that busy life he never was too busy to let his true feelings come out, never too busy to love the sunshine and birds and flowers. The wonderful hold he had on his students and followers shows his never-slacking enthusiasm, and even to-day this is felt by reading his travels and his scientific addresses and papers, or by following his life, so admirably recounted by Fries. He trained himself to see and note whatever was essential and to express this in as few words and as directly as possible, and yet it seems natural for him to pass from scientific description to poetic prose full of the beautiful Northern imagery, which is so rich in the Swedish language. Indeed there is so much of the imaginative in his writing that the Swedes, as Levertin has done, like to name him with their poets.

He starts on his scientific trips with a bird-like delight in the outdoors much like that of the old ballads:

Hit befel on Whitsontide,
 Erly in a May mornynge,
 The son vp feyre can shyne,
 And the briddis mery can syng.

“This is a mery mornynge,” seid Litull John.
 “Be hym that dyed on tre;
 A more mery man then I am one
 Lyves not in Christiantë.” (Robin Hood and the Monk.)

Is this very different from the spirit of Linné when he set out from Upsala to study the plants and the rocks and the people of Lapland?

I journeyed from Upsala town the 12th of May, 1732, which was a Friday, 11 o'clock A.M., when I was 25 years old, all but twelve hours. Now began all the ground to delight and smile, now comes beautiful Flora and sleeps with Phœbus.

*Omnia vere vigent et veris tempore florent
 Et totus ferret Veneris dulcedine mundus.*

Now stood the winter rye quarter of an ell tall, and the grain had newly shown a blade. The birch began now to burst forth, and all leafy trees to show their leaves, except the elm and aspen. . . . The lark sang to us the whole way, quivering in the air.

Ecce suum tirile, tirile, suum tirile tractat.

The sky was clear and warm, the west wind cooled with a pleasant breeze, and a dark hue from the west began to cover the sky. . . . The woods began to increase more and more, the sweet lark which ere now had delighted our ears, deserted us, but yet another one meets us in the woods with as great a compliment, namely the thrush, *Turdus minor*, who, when she on the highest fir-top plays to her dearest, also lets us joy therein. Yes, she tunes in so high with her varied notes that she often overmasters the nightingale, the master of song.

As he goes on and the season advances he notes that "no place in Sweden is pleasanter to travel through in the summer" than the woods of pine, fir and "overflowing" (ofverflödlig) birch. He says that although summer may be shorter here than anywhere else in the world, nowhere is it pleasanter, and he holds the midnight sun as not the least of nature's miracles. On midsummer day he gives praise for the beauty of summer and of spring, and for the air, the water, the green plants and the song of birds.

On this Lapland journey, Linné became fascinated with the little creeping pink-and-white twin-flower, calling it by his own name, and it has ever since been known as the linnæa (*Linnæa borealis* Gronovius), and even when found in the cool shades of the Adirondacks or on the pine-clad slopes of the Sierras it seems to carry with it some of the dreamy cheerfulness of the Northern midsummer.

When he gets up into the mountains, he revels in the freedom of the bracing mountain air and rejoices to find the flowers more numerous and more beautiful than he expected, and when he climbs Vallivare there is so much that is new he imagines himself in a new world. He goes through a cold driving snow-storm as he crosses over the fjäll into Norway and looks down on the landscape below:

When we at last came down what pleasure did I not find for my tired body? I came then out from a cold and frozen fjäll down into a warm and seething valley (I sat me down to eat wild strawberries [smultron]); for snow and ice I saw green plants standing in their sweetest bloom (such high grass had I never seen in any place); for violent weather a striking scent from *Trifolio florento* [flowering clover] and other plants. . . . I was able to cool myself with cow-milk and refresh myself with food, also to sit in a chair.

Perhaps only those who have feasted on the wild strawberries (smultron) of Scandinavia can appreciate how that little naïve touch makes the whole scene full of life. From a purely scientific point of view it might have done to have told us that as he reached a certain altitude on his descent he found certain flowers in bloom and the fruit of certain plants already ripe. But personally I am glad to have my mouth, like his, water over those smultron.

And I feel sure that he had the smultron still in mind when years afterward he rejoiced at bidding a disciple God-speed on a journey to Lapland, sending with him greetings to the Lapland fjälls and flowers, and assuring him that the trip will give him memories that will be a life-long pleasure. The joy of the fjäll comes on him again in the same way as Wordsworth's heart, filled with pleasant memories of his chance walk by the shore of Ullswater, "dances with the daffodils."

Even more noteworthy than in his travels are the expressions of his sympathetic love for nature in his scientific papers and treatises. In

his "Deliciæ Naturæ" he classifies the plants by comparing their families to a great commonwealth, saying of the grass:

The grass, in its simple dräkt [costume] makes up here the peasant class; it is the most numerous and contributes the most, it takes care of itself the best, although it is daily tramped upon and vexed.

To one with such a true, sympathetic and enthusiastic love for nature, life must needs be full of meaning. There is a saying in Swedish, "Som man ropar i skogen, får man svar" (As one calls into the woods so is he answered). Linné called into the woods with a voice of love, and in like tones all nature answered. He took delight in coming upon the creeping twin-flower trailing through the pine-woods, in listening to the little chaffinch (bofink) with a great butterfly in his mouth calling home his children to dinner. He marveled at the endurance of the Lapps in going over mountains and with a human sympathy entered into their fresh, free life. He enjoyed watching the young men and women of Skåne dance about the midsummer may-pole. For him everything is worth observing and noting. With so many things to see, to think about and to love, his life is one of sunshine, and he is full of thankfulness for having been permitted to know and enjoy so much. Truly to such a human heart, as to Wordsworth,

the meanest flower that blows can give
Thoughts that do often lie too deep for tears.

Linné is not like the swine which "become fat on acorns, but not once look up at the tree from which the fruit fell, much less think upon him who established the tree so splendidly." He says of himself:

I sought after God's footsteps over nature's plain and perceived in every one, even in those I could scarcely discern, an unending wisdom and power, an impenetrable completeness.

And again after declaring that God's wisdom is shown in the smallest creature as well as in the elephant and is as worthy of wonder, he repeats a favorite phrase of his:

Great are the works of the Lord, and the one who takes heed of them he has joy therein (Store äro Herrans verk, och den som uppå dem aktar, han hafver lust deraf).

To appreciate fully Linné's love for nature we must remember that he began life early in the eighteenth century, in the very midst of the classical age of European life and letters. It was an age in which emphasis was placed upon the conventional, the formal, an age in which feeling and enthusiasm were restrained, an age of the court and the city, rather than of the country and nature. In the romantic movement, which meant a breaking away from artificial classicism, one of the most important features was the "return to nature." In the beginning of

the eighteenth century no poet thought of writing about the birds and flowers, or if he did, of using anything but stilted and conventional phrases. In such an age, long before Burns and Wordsworth, before even Rousseau, Linné leaves the conventional city for the garden, the äng, the barrskog, the fjäll; he is bold enough to neglect the conventionalized nightingale in his joy over the thrush; he ignores the conventional rules and models of writing, and in his own simple and direct way sets down truthfully the things he has seen with his own eyes and felt with his own heart; he leads the way not only for a more scientific study of nature, but also for a more poetic love for nature. With the eighteenth-century world sleeping through a musicless night, Linné's enthusiastic love for nature, so joyously and continuously expressed, must have come like the dawn song of birds calling to awake. And it is not unreasonable to suppose that through his writings and through the hundreds of students who were held at Upsala by his powerful magnetism, something of his inspiring love for nature should have been spread through Europe and all the world and have helped in leading men back to the great outdoors.

To some it may seem curious that Linné looked upon flowers and nature, at the same time from the scientific and the poetic points of view. We have, of course, plenty of amateurs who have a love for nature without a true knowledge, and we have scientists who see only the material object under their microscope and who feel or love nothing. But the examples of such scientists as Linné and Agassiz and many more show us that a scientist need not be fossilized, nor a mere instrument for dissecting, recording and classifying. A little of the poetic feeling, a little of the love and enthusiasm of Linné need not interfere with the worth of scientific work.

With the love for nature developed more, and, perhaps with the scientific attitude developed somewhat less, we have the naturalists, men like Gilbert White, Thoreau, Burroughs and Muir. These are the men who with loving and appreciative eyes observe what is near at hand. Their value lies in that they see clearly, accurately and with a true sympathy, and in that they let us share in their joy over nature. Reading their writings is like walking through the fields and woods. It opens our eyes and ears, it opens our hearts and souls, and makes us feel with David Starr Jordan: "Nowhere is the sky so blue, the grass so green, the sunshine so bright, the shade so welcome, as right here, now, to-day." Welcome indeed are the words and example of every observer who can help us see and enjoy for ourselves our own sky and grass and sunshine. Linné does this, and therefore is to be placed with the naturalists.

With the emotional, imaginative side of the love for nature still more developed, but with the same close observation and appreciation of

truth and reality, we have the poets, the nature poets of a high class, for we are not now concerned with the clever versifiers, the bookish imitators, nor with those who see nature and life morbidly or fantastically, through false and distorted glasses. The true poets, like Homer, or Shakspeare, or Tennyson, see nature as truthfully as the scientists, they seize upon what is significant for their purpose, they base their imagination upon what is real and vital; they are like Wordsworth's skylark, singing up into the sky but keeping heart and eye on the nest upon the ground,

Type of the wise, who soar, but never roam—
True to the kindred points of Heaven and Home.

These poets are not the ones to make the nightingale and skylark sing in America, nor to be accused by Ruskin of pathetic fallacy in making their words express emotions which they know to be false. They are the ones who have a sincere insight into life and nature and express their true thought and feelings in all the imaginative beauty of their art. Linné was like a true poet in that he was capable of poetic imagination and beautiful expression, perhaps the chief difference being that with him this was incidental, with the poet supreme.

Like the scientists, Linné saw nature accurately; like the naturalists, he saw it sympathetically; like the poets, he saw it beautifully; like all of them, he saw it truthfully. Further still, like the prophets and seers, he saw the significance of things in the universe, he looked through what Carlyle calls the "show of things" into the things themselves, he penetrated into Goethe's "open secret."

The more we walk with Linné in the gardens, the ängs, the fjälls of his beloved Sweden, the more we shall appreciate how his inborn love for nature, showing itself in so many ways, was a vital part of his life, and the more we shall share in his joy in the works of creation. His love for nature leaves with us a memory, like that of a glorious morning, a sunshiny day, a calm and peaceful evening. Such a love for nature takes us out from the pent-up city and shows us, as it did Keats, how sweet it is

to look into the fair
And open face of heaven.

Such a love for nature fills our hearts with sunshine and joy, and, as it did for Linné, he who loved the little twin-flower, it opens our eyes to the truth and to the beauty of nature and of life.

EARLY MOVEMENTS IN THE UNITED STATES FOR A
NATIONAL OBSERVATORYBY CHARLES OSCAR PAULLIN,
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DURING the first half of the nineteenth century, the federal government was exceedingly penurious in its encouragement of knowledge and learning. Many members of congress believed that appropriations for this purpose were unconstitutional. Those members who were imbued with the theory of states-rights saw in the establishment of scientific bureaus an undue extension of the powers of the central government. Moreover, the interests of parties, classes and individuals were involved in these questions; and as a result the cause of knowledge suffered. Culture and education were less widely diffused than at the present time, and the people therefore were generally indifferent to the national encouragement of science. Even work of great practical value, such as the survey of the coast, the preparation of a nautical almanac and the study of winds and weather was regarded by many as unnecessary. The inland states were disinclined to vote money for these purposes, since it would chiefly benefit the seaboard. A few progressive men, the choice spirits of their time, however, early advocated the establishment of a national astronomical observatory.

For many years various projects for a national institution devoted to the study of astronomy were formed. Thomas Jefferson, as an amateur, made astronomical observations; and at one time had a plan for a national observatory. Some of the leading professors of Bowdoin College and citizens of Brunswick, Maine, early memorialized congress to establish an observatory in their town. Writing in 1824, H. C. Knight favored the establishment of a "National Observatory, whose top, with a sublimer intent than that of ancient Babel, should look into the sky; with complete astronomical apparatus, and resident professors, and salaries so liberal as to induce the most elevated intellects to devote their entire energies, during life, in tracing the marches and counter-marches of the planets, and deciphering the golden hieroglyphics of heaven. Now Rittenhouse is above the stars, let Doctor Bowditch sit up in the top-tower, and be the first Herschel of America." When, in the thirties of the last century, the founding of a naval academy was being discussed, it was proposed to connect with it an astronomical observatory, whose professors should constitute a "board of longitude."

Many other isolated suggestions and proposals for an observatory might be mentioned.

There were four general movements for a national observatory. Each of these extended over a considerable period of time, and each was originated and chiefly promoted by a single man—by F. R. Hassler, William Lambert, John Quincy Adams and James M. Gilliss. The Hassler movement is connected with the founding of the Coast Survey, and the Lambert movement with the establishment in the United States of a first meridian. The movement of Adams formed a part of his plan for the promotion by the federal government of science, learning and public improvements. The undertakings of Gilliss on behalf of an observatory grew out of his actual experience as an astronomical observer in a little building on Capitol Hill in Washington. Each of these movements will be briefly considered.

In 1807 President Jefferson obtained a law providing for the survey of the coasts of the United States. This was the initial legislation in the establishment of the United States Coast Survey. F. R. Hassler was selected by Jefferson and his secretary of the treasury, Albert Gallatin, to undertake the preliminary work. Hassler was a Swiss refugee, and at one time was connected with a trigonometrical survey of his native land. In 1807 he was appointed a professor of mathematics at the Military Academy at West Point. He was one of the most distinguished of the early mathematicians and surveyors of the United States. Between 1807 and 1816, Hassler gave much attention to the preliminaries for the survey of the coast. He drew up a plan of operations. This provided for two astronomical observatories. They were to form the fixed points to which the survey was to be referred. They were to be used in determining time and longitude. Hassler, however, had in mind not merely the needs of the Coast Survey, but the advancement of scientific knowledge as well. The two observatories, he said, "will be permanent scientific establishments." He wished to locate one of them in Maine, and the other in lower Louisiana—that is, as far apart as possible. "Still, various considerations might occasion and favor the desire of placing one of these observatories in the city of Washington, as observatories are placed in the principal capitals of Europe, as a national object, a scientific ornament and a means of nourishing an interest for science in general." Here should be deposited the standards of weights and measures, and the chronometers and library of the Coast Survey. Hassler drew up a plan for the construction of an observatory at Washington, and he chose a location for it, "a part of the hill north of the Capitol."

From August, 1811, until October, 1815, Hassler was in England and on the continent, where he was sent to procure the necessary apparatus for the survey of the coast. The war of 1812 retarded and

interrupted his work. He succeeded, however, in obtaining a most superior collection of instruments and books. Among the instruments for the observatories were two five-foot transits of improved construction, made by Edward Troughton, of well-known contemporary fame; and two astronomical clocks, manufactured by "William Hardy from Scotland, residing in London, and who is eminent for various valuable inventions in the line of clock work and chronometer making, and for the very superior execution of all his works." Hardy had constructed similar clocks for the observatories of Greenwich and Glasgow. Hassler also purchased some books for his observatories. In 1816 his astronomical plans received the endorsement of President Madison and Secretary of the Treasury Dallas.

Under the direction of Hassler the field-work of the survey of the coast was begun in the summer of 1816, but it was suddenly brought to a close by the repeal in the spring of 1818 of a part of the act of 1807 authorizing the survey. The astronomical observatories had not yet been established. Hassler was still of the opinion that at least one of them was indispensable. When congress in 1832 revived the act of 1807, it concluded that an astronomical observatory was not necessary for the survey of the coast. The act of 1832 contained a provision that nothing in this act nor in that of 1807 "shall be construed to authorize the construction or maintenance of a permanent astronomical observatory." The establishment of an observatory had now become a favorite project of John Quincy Adams, and the democrats during his administration had especially opposed and ridiculed it. They were determined not to leave a loop-hole in the legislation for the Coast Survey, by means of which Adams might be able to gratify his long-cherished desire. The law of 1832 gave a quietus to Hassler's plan of attaching an observatory to the Coast Survey.

The second general movement for an astronomical institution under federal control was that of William Lambert, at one time a resident of Virginia and later of the District of Columbia. Lambert's movement began with his attempts to obtain legislation providing for the establishment of a prime meridian of the United States for the reckoning of longitudes. He believed that Washington in laying out the seat of government had designed that the center of the Capitol should mark the first meridian of this country. Lambert brought the subject to the attention of congress by a memorial to the house, dated City of Washington, December 15, 1809. He declared that the establishment of a first meridian was worthy of the consideration and patronage of the national legislature, since a further dependence upon Great Britain and other foreign nations would thereby be entirely removed; and he submitted a series of astronomical and mathematical papers dealing with the subject. One of these was an abstract of calculations made

by himself with a view to ascertaining the longitude of the Capitol. His figures were based upon an occultation of the star Alcyone, one of the Pleiades, by the moon, which was observed near the President's house on October 20, 1804. Lambert succeeded in deriving the capitol's approximate longitude. On March 28, 1810, a committee of the house to which Lambert's memorial had been referred recommended the passage of a law authorizing the president to cause the longitude of Washington west of Greenwich to be ascertained with the greatest possible degree of accuracy, and empowering him to procure for this purpose the necessary astronomical instruments. The movement to establish a first meridian impressed the members of congress favorably, since it seemed to involve a declaration of astronomical independence from Great Britain. A native republican meridian was to be substituted for an alien monarchical one.

On January 21, 1811, the house referred Lambert's documents to a second committee, which a month later asked to be discharged. Apparently, it felt itself unequal to the solution of the astronomical problems involved in the learned formulæ of the memorialist. For an expert opinion the house now rather oddly turned to James Monroe, Madison's secretary of state. After keeping the papers more than a year, Monroe on July 3, 1812, made a report in which he confessed his ignorance of the scientific aspects of the subject. He had no hesitation, however, in declaring that a first meridian should be established at Washington. This, he said, should be done with the greatest mathematical precision by means of a long series of observations with astronomical instruments. An "observatory would be of essential utility. It is only in such an institution, to be founded by the public, that all the necessary implements are likely to be collected together, that systematic observations can be made for any great length of time, and that the public can be made secure of the result of the labors of scientific men. In favor of such an institution it is sufficient to remark, that every nation which has established a first meridian within its own limits has established also an observatory. We know that there is one at London, at Paris, at Cadiz, and elsewhere."

Monroe's letter together with Lambert's documents were referred to a committee of the house, to which Dr. Samuel Mitchill, of New York, was chairman and John C. Calhoun a member. On January 20, 1813, this committee made a report, which was accompanied by a bill "authorizing the establishment of an Astronomical Observatory." The bill provided for the erection of an astronomical observatory on public ground within the city of Washington, and for the procuring of proper telescopes, instruments and furniture for the same. The president was to direct the construction of the building, and was to prescribe rules for the government of the new institution. He was to appoint, subject

to the confirmation of the senate, a "person of competent learning and skill, to be called the National Astronomer," who was to have charge of the observatory. The bill was never voted upon. The war with England at this time occupied the attention of congress to the exclusion of less pressing matters. Moreover, Lambert, who was diligent in promoting his project, was not in Washington for the larger part of the years 1813 and 1814.

From 1815 to 1824, Lambert pursued his hobby with the assiduity of an enthusiast. Finally his perseverance was rewarded by the passage of a joint resolution of congress on March 3, 1821, directing the president to cause the work of ascertaining the longitude of the Capitol to be undertaken. On April 10, President Monroe ordered Lambert to make the necessary "observations by lunar occultations of fixed stars, solar eclipses, or any other approved method adapted to ascertaining the longitude of the Capitol." In order to have his whole time for his new task, Lambert resigned a clerkship in the War Department. He had, however, no positive assurance that he would be paid for his astronomical work.

Lambert now established a temporary observatory. From the War Department he obtained the loan of some of the instruments which Hassler had procured in Europe for the Coast Survey. Among those that he obtained were a transit instrument, a circle of reflection, an astronomical clock and a chronometer. Rooms for their use and safe-keeping were assigned in the south wing of the Capitol. To be near his work, Lambert moved to the vicinity of the Capitol. He employed William Elliot, then well known in Washington as a teacher of mathematics, as an observer. In order to make accurate transit observations, he established near the Capitol a north-and-south line, by means of concentric circles. Its direction from the transit instrument in the south wing was ascertained with great exactness. The time-pieces were carefully tested and rated.

Lambert made frequent observations during the summer of 1821. From these he deduced new values for the latitude and longitude of the Capitol. On November 8, he made an elaborate report of his work to the president. He also made two supplemental reports, one in March, 1822, and the other in December, 1823. In his report of 1821 he called the attention of the government to the need of a permanent astronomical observatory, in order to ascertain with accuracy the right ascension, declination, latitude and longitude of the moon, planets and stars, and to compute a nautical almanac. The movement of Lambert for a national observatory seems to have come to an end in 1824. The transit instrument may have been occasionally used on Capitol Hill subsequent to this time. John Quincy Adams has the following entry in his diary for November 19, 1825: "Roberdeau,

Colonel, came at eleven, I walked with him to W. Elliott's on Capitol Hill, where, with a small transit instrument, they observed the passage of the sun over the meridian. Conversation about the erection of an observatory."

The beginning of the movement of John Quincy Adams for a national observatory may be dated with the foregoing entry in his diary. The study of astronomy was for many years a favorite avocation of this illustrious statesman. He often observed and recorded the phenomena of the heavens. He read the works of Newton, Schubert, Lalande, Biot and Lacroix. A report of Adams respecting the establishment of a national observatory has been pronounced by a competent judge "well worthy the perusal of every lover of the exalted science of astronomy, both for the richness of its information and the beauty of its eloquence." In 1823 he offered to give a thousand dollars towards the establishment of an observatory at Harvard University. Writing in 1838, he said that the "observation of the sun, moon and stars has been for a great portion of my life a pleasure of gratified curiosity, of ever-returning wonder, and of reverence for the Creator and mover of these unnumbered worlds." In 1843, notwithstanding his advanced age and the poor accommodations for traveling, he accepted the invitation of the Cincinnati Astronomical Society to lay the corner-stone of their new observatory. His oration on this occasion has been called an "outline of the history of astronomy." Such was his interest in this science, and in its advancement through public means, that the founding of a national observatory became one of the cherished projects of his later life.

In his first annual message to congress, dated December 6, 1825, President Adams recommended the establishment of an astronomical observatory, either as a part of a national university or as a separate institution; and also the providing for the "support of an astronomer, to be in constant attendance of observation upon the phenomena of the heavens, and for the periodical publication of his observations." Respecting the failure of the United States to do its part in the advancing of astronomical science, Adams wrote with his accustomed candor and vigor: "It is with no feeling of pride as an American, that the remark may be made, that, on the comparatively small territorial surface of Europe, there are existing upward of one hundred and thirty of these light-houses of the skies, while throughout the American hemisphere there is not one. If we reflect for a moment upon the discoveries, which in the last four centuries have been made in the physical constitution of the universe by means of these buildings and of observers stationed in them, shall we doubt of their usefulness to every nation? And while scarcely a year passes over our heads without bringing some new astronomical discovery to light, which we must fain receive at

second-hand from Europe, are we not cutting ourselves off from the means of returning light for light, while we have neither observatory nor observer upon one half of the globe, and the earth revolves in perpetual darkness to our unsearching eyes?"

As a result of this recommendation a bill was introduced into the house, establishing an observatory in the District of Columbia and authorizing the appointment of an astronomer, two assistant astronomers and two assistants. A committee of the house made a long and favorable report on the subject. The bill was not voted upon.

Adams's recommendation for an observatory formed a part of his policy of nationalism, paternalism and internal improvements. In his first annual message he had also recommended the founding of a national university and of a naval academy, the establishment of a uniform system of weights and measures, and liberal expenditures for roads and canals. This progressive and enlightened policy did not command the support of congress, and its bold announcement early in his administration strengthened the hands of his opponents. His plan for a national observatory they represented as impracticable, and even chimerical. His rhetorical phrase, "light-houses of the skies," was circulated as an illustration of the fancies of his mind, and was used to cast reproach upon his astronomical project. Recognizing the futility of urging the construction of an observatory, Adams did not after the first year of his presidency bring it again to the attention of congress during his term in the White House. For several years he discovered no opportunity for furthering his pet measure.

In December, 1835, President Jackson announced the bequest of a considerable sum of money by James Smithson, of London, for the purpose of founding in Washington an institution "for the increase and diffusion of knowledge among men." In the house the message of the president and accompanying papers on this subject were referred to a committee of which Adams was chairman. He thus became intimately connected with the work of obtaining possession of the Smithson funds and later of deciding on their disposition and application. For more than ten years he was chairman of committees of the house on the Smithson bequest. Not until 1838, when all the requirements of the law had been complied with, did the United States obtain possession of the money. Our success in this particular was first made known in Washington in June, 1838. Adams lost no time in calling upon President Van Buren, and in explaining his views respecting the application of the income to be derived from the fund. On this subject he had probably made up his mind soon after the bequest was announced in 1835. He says that he suggested to Van Buren the "establishment of an astronomical observatory, with a salary for an astronomer and assistant, for nightly observations and periodical publications; annual

courses of lectures upon the natural, moral and political sciences. Above all no jobbing, no sinecure, no monkish stalls for lazy idlers."

Adams improved every opportunity for furthering his plan. In October, 1838, he wrote a long letter to the secretary of state ardently advocating the erection of an observatory from the Smithsonian fund. He estimated that for the founding of the institution two hundred and ten thousand dollars would be necessary. This he shortly raised to three hundred thousand dollars. In January, 1839, he presented his views on the subject in a resolution which he reported to the house. In 1839 he obtained from Rev. George B. Airy, the astronomer royal of Great Britain, a detailed statement respecting the expenditures of the Greenwich observatory. In each of the years 1839, 1840, 1842 and 1844, as the chairman of the committee of the house on the Smithsonian fund, he introduced a bill providing for an astronomical observatory. In the report which accompanied the bill of 1840, Adams, with a display of much learning, and some rhetoric, briefly recounted the history of astronomy, beginning with the first chapter of Genesis and ending with the founding of the observatory of Pulkowa near St. Petersburg in 1839.

The more ardently Adams advocated his favorite measure the less likelihood it had of meeting the approval of congress. Respecting the proper application of the income arising from the fund, the senate differed from the house. It wished to found one or more schools of learning and to encourage education, and it would not listen to Adams's proposal for a national observatory. On this latter point Adams's democratic opponents in congress were determined not to yield. The law of August 10, 1846, which provided for the application of the income of the Smithsonian fund, therefore, while it followed the general lines laid down by Adams, contained no provision for an astronomical observatory.

The fourth general movement for a national observatory is that with which the name of Lieutenant James M. Gilliss is connected. The scientific achievements of Gilliss are more remarkable than those of any other officer of our navy. He was wont to attribute his first impulses along scientific lines to a rather insignificant incident in his career. When he first came to Washington on duty as a midshipman, he heard the officers of the navy stigmatized as incompetent to conduct a scientific enterprise. He at once resolved to disprove the charge in his own person. In 1833 he obtained leave to prosecute a course of studies at the University of Virginia. Excessive application soon so impaired his health that he was compelled to give up his work before he had been a year in residence. In 1835 he resumed his studies at Paris and pursued them for six months.

In 1830 the Navy Department established in Washington the

Depot of Charts and Instruments. It was given charge of the unused charts and instruments of the navy. It distributed these necessary articles to the naval ships. It repaired and rated the chronometers. For the latter purpose simple meridian observations were necessary. Lieutenant Charles Wilkes, who was made superintendent of the depot in 1833, removed it to Capitol Hill. Here he erected a small observatory, 14 feet long, 13 feet wide, and 10 feet high. He installed in it one of the five-foot transit instruments, which Hassler had procured for the Coast Survey.

In 1836 Gilliss was detailed to duty at the Depot of Charts and Instruments. He shortly began to make astronomical observations in addition to those necessary for the rating of the chronometers. In the winter of 1837-8 he observed certain culminations of the moon and stars. In August, 1838, the Wilkes exploring expedition sailed from the United States on its famous voyage to the Pacific and Antarctic seas. Wilkes suggested to the secretary of the navy that in determining the longitude of the various stations of his expedition, observations made in the United States would be of the greatest value. Accordingly, Secretary of the Navy Paulding issued instructions to Gilliss to observe, during the absence of the exploring expedition, culminations of the moon and stars, eclipses of the moon, sun and Jupiter's satellites, falling stars, and any striking astronomical phenomena. He was to make also meteorological and magnetic observations.

Gilliss immediately made thorough preparations for his new work. He procured a 42-inch achromatic telescope mounted parallaxically, a variation transit, an 8-inch dip circle, and a sidereal chronometer. He imported several new meteorological and magnetic instruments, to accommodate which he erected a small frame building fifty feet south of the observatory on Capitol Hill. Three or four additional passed midshipmen were attached to the depot to assist in its new work. This began in September, 1838, and did not end until June, 1842. All the astronomical observations, with the exception of those for two days in May, 1841, when Gilliss was sick, and a part of those for two other days, were made personally by Gilliss. The average time of his daily employment throughout the period was twelve hours, and he was often on his feet twenty hours out of twenty-four. The number of transits recorded exceeded ten thousand, and embraced those of the moon, planets, and about eleven hundred stars. The average number of lunar culminations observed was one hundred and ten, and of lunar occultations about twenty. The meteorological and magnetic observations were made bi-hourly day and night. All these observations were reduced by Gilliss, and were published by the government in 1845 and 1846 in two octavo volumes containing more than thirteen hundred

pages. These volumes were highly commended by the astronomers of Europe as well as those in America. They stand as a lasting monument to the great energy, indefatigable industry, scientific ardor, and consummate skill as an observer, of this young naval lieutenant.

The difficulties under which Gilliss performed his scientific work were exceedingly great. His many routine duties as superintendent of the Depot of Charts and Instruments had to be attended to daily. His transit instrument was defective. The little building used as an observatory was most inadequate. The observing slits originally extended to within three feet of the ridge-pole on each side, thus precluding all observations between 26° and 53° north declination, a region which actually includes a part of the moon's path. This defect was partly remedied by extending the aperture some five and a half degrees on the southern side, the utmost that the strength of the building permitted. One seventh of the standard stars of the Nautical Almanac still remained hidden from view. At the age of twenty-seven, Gilliss began his work without the aid or counsel of fellow scientists. Indeed, there were but few practical astronomers in the United States whom he might have consulted had he been acquainted with them. Not until 1840 did he obtain advice and assistance. He then received valuable counsel from the astronomers Richard Sheepshanks and Sears C. Walker. Gilliss says that he commenced his observations "with but little experience in the manipulation of fixed instruments; without a book relating to the subject in any manner, except Pearson's Introduction and Vince's Astronomy." He had never seen a volume of the annals of any of the European observatories.

Dr. B. A. Gould, a most competent judge, says that it was Lieutenant James M. Gilliss, "who first in all the land conducted a working observatory, he who first gave his whole time to practical astronomical work, he who first published a volume of observations, first prepared a catalogue of stars, and planned and carried into effect the construction of a working observatory as contrasted with one intended chiefly for purposes of instruction." The last clause has reference to Gilliss's work of planning and constructing the Naval Observatory. In 1841 he obtained authority to import a meridian circle for his little establishment on Capitol Hill, in Washington. Since his narrow quarters here afforded no room for the new instrument, he availed himself of the opportunity to urge the construction of a permanent observatory. Gilliss says that as the observations which he began in 1838 progressed, the "unsuitableness of the building, the defects of the transit instrument, the want of space to erect a permanent circle, and the absolute necessity of rebuilding the observatory in use, became each day more urgent." At his earnest request the commissioners of

the navy on November 30, 1841, recommended to the secretary of the navy the erection of a permanent depot for the charts and instruments belonging to the navy. They estimated the cost of site and buildings at \$50,000. In his annual report to the president, dated December 4, 1841, the secretary of the navy approved the recommendation of the commissioners. From President Tyler the proposal for a new depot or observatory passed to congress, and especially to the house committee on naval affairs.

One of the principal members of this committee was Francis Mallory, a Whig representative from Virginia. On March 15, 1842, Mallory reported to the house a bill which provided for the construction of a depot of charts and instruments at a cost of \$25,000. A report which accompanied the bill set forth the inadequacy of the accommodations on Capitol Hill, and the need of extending the work and usefulness of the old depot. According to Mallory the existing observatory was so frail that twice during the winter of 1841-1842 its doors had been blown off and the instruments had been left exposed to the weather. He proposed that the new depot should have increased accommodations for the study of hydrography, astronomy, magnetism and meteorology. In respect to astronomy, he said, that "not only has the navy failed to contribute to the common stock from which all our navigators borrow, but our country has never yet published an observation of a celestial body, which bore the impress 'by authority'"; and that until Gilliss began his work in 1838, no continuous astronomical observations had been made under the direction of the government.

An account of the movement in congress has been left us by Gilliss:

Much delay occurred with the Naval Committees in congress. The Hon. Francis Mallory, to whom it was referred by the House committee, espoused the cause warmly, but the majority kept aloof from the depot (although so near) until the entire winter passed away. Finally, on the 15th March, 1842, I succeeded in persuading the only member of the committee to visit the observatory who was skeptical, and on that very day a unanimous report and bill were presented to the House of Representatives. Believing the chances of success would be greater if a bill could be passed by the Senate, by the advice of Mr. Mallory, I waited on the Naval Committee of the Senate, but my entreaties for a personal inspection of our wants were put off from time to time. The question was probably decided by an astronomical event.

At a meeting of the National Institute, at which the Hon. William C. Preston was present, I gave notice of having found Encke's comet with the $3\frac{1}{2}$ feet achromatic, the comet being then near its perihelion. A few days subsequently I made what was intended to be a last visit to the chairman of the Senate committee, and found Mr. Preston with him. As soon as I began the conversation about the little observatory, Mr. Preston inquired whether I had not given the notice of the comet at the institute, and immediately volunteered, 'I will do all I can to help you.' Within a week a bill was passed by the Senate.

It is hardly necessary to trace its progress in the House. A majority was known to be favorable, but its number on the calendar, and the opposition of one or two members, were likely to prevent action upon it; and that it did receive the sanction of the House of Representatives at the last hour of the session of 1841-42, the navy is indebted to the untiring exertions of Dr. Mallory.

Unquestionably, Gilliss is right in giving Mallory much credit for the passage of the bill. No one, however, played a more prominent part than Gilliss himself, whether in initiating the movement for the new depot or in lining up its supporters in congress. Moreover, his signal success at the little observatory on Capitol Hill must have disposed many members to favor the measure. Other influences were working in the same direction. John Quincy Adams's agitation bore fruit for Gilliss. For several years public sentiment in behalf of a national observatory had been increasing. Observatories were being established at several of the leading schools in the United States: in 1838, at Western Reserve College, by Elias Loomis; in 1839, at Harvard College, by W. C. Bond; in 1840, at the Philadelphia High School, by Sears C. Walker and E. O. Kendall; and in 1841, at the Military Academy, by W. H. C. Bartlett.

The act of August 31, 1842, provided for the construction of a depot of charts and instruments, or the United States Naval Observatory, as the new institution came to be called. The new buildings were appropriately constructed under the direction of Gilliss. When they were completed in October, 1844, he turned them over to Lieutenant Matthew F. Maury, who was the first superintendent of the Naval Observatory. The success of Gilliss's efforts shortly brought to an end all other attempts to found a national observatory. John Quincy Adams finally accepted the Naval Observatory as a substitute for his more ambitious establishment. In April, 1846, he said that he was "delighted that an astronomical observatory—not perhaps so great as it should have been—had been smuggled into the number of the institutions of the country, under the mask of a small depot for charts."

ADDRESS OF THE PRESIDENT TO THE ENGINEERING
SECTION OF THE BRITISH ASSOCIATION FOR
THE ADVANCEMENT OF SCIENCE¹

By SILVANUS P. THOMPSON, Sc.D., F.R.S.,
PAST PRESIDENT OF THE INSTITUTION OF ELECTRICAL ENGINEERS

IT would be impossible for any assembly of engineers to meet in annual gathering at the present time without some reference to the severe loss which the profession has so recently sustained by the death of Sir Benjamin Baker. Born in 1840, he had attained while still a comparatively young man to a position in the front rank of constructive engineers. His contributions to science cover a considerable range, but were chiefly concerned with the strength of materials, into which he made valuable investigations, and with engineering structures generally. His name will doubtless be chiefly associated with the building of great bridges, to the theory of which he contributed an important memoir entitled "A Theoretical Investigation into the Most Advantageous System of Constructing Bridges of Great Span." In this work he set forth the theory of the cantilever bridge. Upon the plan there laid down he built the Forth Bridge, besides many other large bridges in various parts of the world. With that memorable structure, completed in 1890, his name will ever be associated; but he will be remembered henceforth also as the engineer who was responsible for the great dam across the Nile at Assouan, a work which promises to have an influence for all time upon the fortunes of Egypt and upon the prosperity of its population. Sir Benjamin Baker was, moreover, closely associated with the internal railways of London, both in the early days of the Metropolitan Railway and in the later developments of the deep-level tubes. He was elected a fellow of the Royal Society in 1890, became president of the Institution of Civil Engineers in 1895, and was a member of council of the Institution of Mechanical Engineers, besides being an active member of the Royal Institution and of the British Association. He was also a member of the council of the Royal Society at the time of his death.

He enjoyed many honorary distinctions, including degrees conferred by the Universities of Cambridge and Edinburgh. In 1890 there was conferred upon him the title of K.C.M.G., and in 1902 that of K.C.B.

¹ Leicester, 1907. The address concluded with a section on the education of engineers.

He had but just returned from Egypt, whither he had gone in connection with the project for raising the height of the Assouan dam, so as to increase its storage to more than double the present volume, when he died very suddenly on May 19, in his sixty-seventh year.

The Development of Engineering and its Foundation on Science

We live in an age when the development of the material resources of civilization is progressing in a ratio without parallel. International commerce spreads apace. Ocean transport is demanding greater facilities. Steamships of vaster size and swifter speed than any heretofore in use are being built every year. Not only are railways extending in all outlying parts of the world, but at home, where the territory is already everywhere intersected with lines, larger and heavier locomotives are being used, and longer runs without stopping are being made by our express trains. The horsed cars on our tramways are now being mostly superseded by larger cars, electrically propelled and traveling with greatly increased speeds. For the handling of the ever-increasing passenger traffic in our great cities electric propulsion has shown itself a necessity of the time; witness the electric railways in Liverpool and the network of electrically worked tube railways throughout London. In ten years the manufacture of automobile carriages of all sorts has sprung up into a great industry. Every year sees a greater demand for the raw materials and products, out of which the manufacturer will in turn produce the articles demanded by our complex modern life. We live and work in larger buildings; we make more use of mechanical appliances; we travel more, and our traveling is more expeditious than formerly; and not we alone but all the progressive nations. The world uses more steel, more copper, more aluminium, more paper; therefore requires more coal, more petroleum, more timber, more ores, more machinery for the getting and working of them, more trains and steamships for their transport. It requires machines that will work faster or more cheaply than the old ones to meet the increasing demands of manufacture; new fabrics; new dyes; even new foods; new and more powerful means of illumination; new methods of speaking to the ends of the earth.

We must not delude ourselves with imagining that the happiness and welfare of mankind depend only on its material advancement; or that moral, intellectual and spiritual forces are not in the ultimate resort of greater moment. But if the inquiry be propounded what it is that has made possible this amazing material progress, there is but one answer that can be given—science. Chemistry, physics, mechanics, mathematics, it is these that have given to man the possibility of organizing this tremendous development. And the great profession

which has been most potent in applying these branches of science to wield the energies of nature and direct them to the service of man has been that of the engineer. Without the engineer how little of all this activity could there have been; and without mathematics, mechanics, physics and chemistry, where were the engineer?

If looking over this England of Edward the Seventh we try to put ourselves back into the England of Edward the Sixth—or for that matter of any pre-Victorian monarch—we must admit that the differences to be found in the social and industrial conditions around us are due not in any appreciable degree to any changes in politics, philosophy, religion, or law, but to science and its applications. If we look abroad, and contrast the Germany of Wilhelm the Second with the Germany of Charles the Fifth, we shall come to the like conclusion. So also in Italy, in Switzerland, in every one indeed of the progressive nations. And it is precisely in the stagnant nations, such as Spain, or Servia, where the cultivation of science has scarcely begun, that the social conditions remain in the backward state of the middle ages.

Interaction of Abstract Science and its Applications

In engineering, above all other branches of human effort, we are able to trace the close interaction between abstract science and its practical applications. Often as the connection between pure science and its applications has been emphasized in addresses upon engineering, the emphasis has almost always been laid upon the influence of the abstract upon the concrete. We are all familiar with the doctrine that the progress of science ought to be an end in itself, that scientific research ought to be pursued without regard to its immediate applications, that the importance of a discovery must not be measured by its apparent utility at the moment. We are assured that research in pure science is bound to work itself out in due time into technical applications of utility, and that the pioneer ought not to pause in his quest to work out potential industrial developments. We are invited to consider the example of the immortal Faraday, who deliberately abstained from busying himself with marketable inventions arising out of his discoveries, excusing himself on the ground that he had no time to spare for money-making. It is equally true, and equally to the point, that Faraday, when he had established a new fact or a new physical relation, ceased from busying himself with it and pronounced that it was now ready to be handed over to the mathematicians. But, admitting all these commonplaces as to the value of abstract science in itself and for its own sake, admitting also the proposition that sooner or later the practical applications are bound to follow on upon the discovery, it yet remains true that in this thing the temperament of the discoverer

counts for something. There are scientific investigators who can not pursue their work if troubled by the question of ulterior applications; there are others no less truly scientific who simply can not work without the definiteness of aim that is given by a practical problem awaiting solution. There are Willanses as well as Regnaults; there are Whitworths as well as Poissons. The world needs both types of investigator; and it needs, too, yet another type of pioneer, namely, the man who, making no claim to original discovery, by patient application and intelligent skill turns to industrial fruitfulness the results already attained in abstract discovery.

There is, however, another aspect of the relation between pure and applied science, the significance of which has not been hitherto so much emphasized, but yet is none the less real—the reaction upon science and upon scientific discovery of the industrial applications. For while pure science breeds useful inventions, it is none the less true that the industrial development of useful inventions fosters the progress of pure science. No one who is conversant with the history, for example, of optics can doubt that the invention of the telescope and the desire to perfect it were the principal factors in the outburst of optical science which we associate with the names of Newton, Huygens and Euler. The practical application, which we know was in the minds of each of these men, must surely have been the impelling motive that caused them to concentrate on abstract optics their great and exceptional powers of thought. It was in the quest—the hopeless quest—of the philosophers' stone and the elixir of life that the foundations of the science of chemistry were laid. The invention of the art of photography has given immense assistance to sciences as widely apart as meteorology, ethnology, astronomy, zoology and spectroscopy. Of the laws of heat men were profoundly ignorant until the invention of the steam engine compelled scientific investigation; and the new science of thermodynamics was born. Had there been no industrial development of the steam engine, is it at all likely that the world would ever have been enriched with the scientific researches of Rankine, Joule, Regnault, Hirn or James Thomson? The magnet had been known for centuries, yet the study of it was utterly neglected until the application of it in the mariners' compass gave the incentive for research.

The history of electric telegraphy furnishes a very striking example of this reflex influence of industrial applications. The discovery of the electric current by Volta and the investigation of its properties appear to have been stimulated by the medical properties attributed in the preceding fifty years to electric discharges. But, once the current had been discovered, a new incentive arose in the dim possibility it suggested of transmitting signals to a distance. This was certainly a possibility, even when only the chemical effects of the current had yet been found out.

Not, however, until the magnetic effects of the current had been discovered and investigated did telegraphy assume commercial shape at the hands of Cooke and Wheatstone in England and of Morse and Vail in America. Let us admit freely that these men were inventors rather than discoverers: exploiters of research rather than pioneers. They built upon the foundations laid by Volta, Oersted, Sturgeon, Henry and a host of less famous workers. But no sooner had the telegraph become of industrial importance, with telegraph lines erected on land and submarine cables laid in the sea, than fresh investigations were found necessary; new and delicate instruments must be devised; means of accurate measurement heretofore undreamed of must be found; standards for the comparison of electrical quantities must be created; and the laws governing the operations of electrical systems and apparatus must be investigated and formulated in appropriate mathematical expressions. And so, perforce, as the inevitable consequence of the growth of the telegraph industry, and mainly at the hands of those interested in submarine telegraphy, there came about the system of electrical and electromagnetic units, based on the early magnetic work of Gauss and Weber, developed further by Lord Kelvin, by Bright and Clark, and last but not least by Clerk Maxwell. Had there been no telegraph industry to force electrical measurement and electrical theory to the front, where would Clerk Maxwell's work have been? He would probably have given his unique powers to the study of optics or geometry; his electromagnetic theory of light would never have leaped into his brain; he would never have propounded the existence of electric waves in the ether. And then we should never have had the far-reaching investigations of Heinrich Hertz; nor would the British Association at Oxford in 1894 have witnessed the demonstration of wireless telegraphy by Sir Oliver Lodge. A remark of Lord Rayleigh's may here be recalled, that the invention of the telephone had probably done more than anything else to make electricians understand the principle of self-induction.

In considering this reflex influence of the industrial applications upon the progress of pure science it is of some significance to note that for the most part this influence is entirely helpful. There may be sporadic cases where industrial conditions tend temporarily to check progress by imposing persistence of a particular type of machine or appliance; but the general trend is always to help to new developments. The reaction aids the action; the law that is true enough in inorganic conservative systems, that reaction opposes the action, ceases here to be applicable, as indeed it ceases to be applicable in a vast number of organic phenomena. It is the very instability thereby introduced which is the essential of progress. The growing organism acts on its environment, and the change in the environment reacts on the

organism—not in such a way as to oppose the growth, but so as to promote it. So is it with the development of pure science and its practical applications.

In further illustration of this principle one might refer to the immense effect which the engineering use of steel has had upon the study of the chemistry of the alloys. And the study of the alloys has in turn led to the recent development of metallography. It would even seem that through the study of the intimate structure of metals, prompted by the needs of engineers, we are within measurable distance of arriving at a knowledge of the secret of crystallogenesis. Everything points to the probability of a very great and rapid advance in that fascinating branch of pure science at no distant date.

History of the Development of Electric Motive Power

There is, however, one last example of the interaction of science and industry which may claim closer attention. In the history of the development of the electric motor one finds abundant illustration of both aspects of that interaction.

We go back to the year 1821, when Faraday, after studying the phenomena of electromagnetic deflexion of a needle by an electric current (Oersted's discovery), first succeeded in producing continuous rotations by electromagnetic means. In his simple apparatus a piece of suspended copper wire, carrying a current from a small battery, and dipping at its lower end into a cup of mercury, rotated continuously around the pole of a short bar-magnet of steel placed upright in the cup. In another variety of this experiment the magnet rotated around the central wire, which was fixed. These pieces of apparatus were the merest toys, incapable of doing any useful work; nevertheless they demonstrated the essential principle, and suggested further possibilities. Two years later, Barlow, using a star-wheel of copper, pivoted so that the lowest point of the star should make contact with a small pool of mercury, found that the star-wheel rotated if a current was sent through the arm of the star while the arm itself was situated between the poles of a steel horseshoe-magnet. Shortly afterwards Sturgeon improved the apparatus by substituting a copper disc for the star-wheel. The action was the same. A conductor, carrying an electric current, if placed in a magnetic field, is found to experience a mechanical drag, which is neither an attraction nor a repulsion, but a lateral force tending to move it at right angles to the direction of flow of the current and at right angles to the direction of the lines of the magnetic field in which it is situated. Still this was a toy. Two years later came the announcement by Sturgeon of the invention of the soft-iron electromagnet, one of the most momentous of all inventions, since upon it practically the whole of the constructive part of electrical

engineering is based. For the first time mankind was furnished with a magnet the attractive power of which could be increased absolutely indefinitely by the mere expenditure of sufficient capital upon the iron core and its surrounding copper coils, and the provision of a sufficiently powerful source of electric current to excite the magnetization. Furthermore, the magnet was under control, and could be made to attract or to cease to attract at will by merely switching the current on or off; and, lastly, this could be accomplished from a distance, even from great distances away. How slowly the importance of this discovery was recognized is now a matter for astonishment. To state that Sturgeon died in poverty twenty-six years later is sufficient to indicate his place among the unrequited pioneers of whom the world is not worthy. Six years elapsed, and then there came a flood of suggestions of electric motors in which was applied the principle of intermittent attraction by an electromagnet. Henry in 1831 and Dal Negro in 1832 produced see-saw mechanisms so operated. Ritchie in 1833 and Jacobi in 1834 devised rotatory motors. Ritchie pivoted a rapidly commutated electromagnet between the poles of a permanent magnet—a true type of the modern motor—while Jacobi caused two multipolar electromagnets, one fixed, one movable, to put a shaft into rotation and propel a boat. A perplexing diminution of the current of the battery whenever the motor was running caused Jacobi to investigate mathematically the theory of its action. In a masterly memoir he laid down a few years later the theory of electric motive power. But in the intervening period, in 1831, Faraday had made the cardinal discovery of the mechanical generation of electric currents by magneto-electric induction, the fundamental principle of the dynamo. Down to that date the only known way—save for the feeble currents of thermopiles—to generate electric currents had been the pile of Volta, or one of the forms of battery which had been evolved from it. Now, by Faraday's discovery, the world had become possessed of a new source. And yet again, strange as it may seem, years elapsed before the world—that is, the world of engineers—discovered that an important discovery had been made. Not till some thirty years later were any magneto-electric machines made of a sufficient size to be of practical service even in telegraphy, and none were built of a sufficient power to furnish a single electric light until about the year 1857. In the meantime in America other electric motors, to be driven by batteries, had been devised by Davonport and by Page; the latter's machine had an iron plunger to be sucked by electromagnetic attraction into a hollow coil of copper wire, thereby driving a shaft and flywheel through the intermediate action of a connecting-rod and crank. Page's was, in fact, an electric engine, with two-foot stroke, single-acting, of between three and four horse-power. The battery occupied about three

cubic feet and consumed, according to Page, three pounds of zinc per horse-power per day. This must have been an under-estimate; for if Daniell's cells were used the minimum consumption for a motor of 100 per cent. efficiency is known to be about two pounds of zinc per horse-power per hour.

Electric Motive Power Impossible in 1857

Upon the state of development of electric motors fifty years ago information may be gleaned from an exceedingly interesting debate at the Institution of Civil Engineers upon a paper read April 21, 1857, "On Electromagnetism as a Motive Power," by Mr. Robert Hunt, F.R.S. In this paper the author states that, though long-enduring thought has been brought to bear upon the subject, and large sums of money have been expended on the construction of machines, "yet there does not appear to be any nearer approach to a satisfactory result than there was thirty years ago." After explaining the elementary principles of electromagnetism, he describes the early motors of Dal Negro, Jacobi, Davenport, Davidson, Page and others. Reviewing these and their non-success as commercial machines, he says: "Notwithstanding these numerous trials . . . it does not appear that any satisfactory explanation has ever been given of the causes which have led to the abandonment of the idea of employing electricity as a motive power. It is mainly with the view of directing attention to these causes that the present communication has been written." He admits that electromagnets may be constructed to give any desired lifting power; but he finds that the attractive force on the iron keeper of a magnet of his own, which held 220 pounds when in contact, fell to thirty-six pounds when the distance apart was only one-fiftieth of an inch. To this rapid falling off of force, and to the hardening action on the iron of the repeated vibrations due to the mechanical concussion of the keeper, he attributed the small power of the apparatus. Also he remarked upon the diminution of the current which is observed to flow from the battery when the motor was running (which Jacobi had, in his memoir on the theory, traced to a counter electromotive force generated in the motor itself), and which reduced the effort exerted by the electromagnets; this diminution he regarded as impairing the efficiency of the machine. "All electromagnetic arrangements," he says, "suffer from the cause named, a reduction of the mechanical value of the prime mover, in a manner which has no resemblance to any of the effects due to heat regarded as a motive power." Proceeding to discuss the batteries he remarked that as animal power depends on food, and steam power on coal, so electric power depends on the amount of zinc consumed; in support of which proposition he cited the experiments of Joule. He gives as his own results

that for every grain of zinc consumed in the battery his motor performed a duty equivalent to lifting eighty-six pounds one foot high. Joule and Scoresby, using Daniell's cells, had found the duty to be equivalent to raising eighty pounds one foot high, being about half the theoretical maximum duty for one grain of zinc. In the Cornish engine, doing its best duty, one grain of coal was equivalent to a duty of raising one hundred and forty-three pounds one foot high. He put the price of zinc at £35 per ton as compared with coal at less than £1 per ton, which makes the cost of power produced by an electric motor—if computed by the consumption of zinc in a battery—about sixty times as great as that of an equal power produced by a steam-engine consuming coal. He concludes that “it would be far more economical to burn zinc under a boiler and to use it for generating steam power than to consume zinc in a battery for generating electromagnetic power.”

In the discussion which followed, several men of distinction took part. Professor William Thomson, of Glasgow (Lord Kelvin), wrote, referring to the results of Joule and Scoresby: “These facts were of the highest importance in estimating the applicability of electromagnetism, as a motive power, in practice; and, indeed, the researches alluded to rendered the theory of the duty of electromagnetic engines as complete as that of the duty of waterwheels was generally admitted to be. Among other conclusions which might be drawn from these experiments was this: that, until some mode of producing electricity as many times cheaper than that of an ordinary galvanic battery as coal was cheaper than zinc, electromagnetic engines could not supersede the steam-engine.” Mr. W. R. Grove (Lord Justice Sir William Grove) remarked that a practical application of the science appeared to be still distant. The great desideratum, in his opinion, was not so much improvement in the machine as in the prime mover, the battery, which was the source of power. At present the only available use for this power must be confined to special purposes where the danger of steam and the creation of vapor were sought to be avoided, or where economy of space was a great consideration. Professor Tyndall agreed with the last speaker, but suggested that there might be some way of mitigating the apparent diminution of power due to the induction of opposing electromotive forces in the machine itself. Mr. C. Cowper spoke of some experiments, made by himself and Mr. E. A. Cowper, showing the advantage gained by properly laminating the iron cores used in the motor. He put the cost of electric power at £1 per horsepower per hour. He deprecated building electric motors with reciprocating movements and cranks; described the use of silver commutators; and mentioned the need of adjusting the lead given to the contacts. There was, he said, no reason to suppose that electric motors could be

made as light as steam-engines. Even in the case of small motors of one tenth or one hundredth of a horse-power, for light work, where the cost of power was of small consequence, a boy or a man turning a winch would probably furnish power at a cheaper rate. Mr. Alfred Smee agreed that the cost would be enormous for heavy work. Although motive power could not at present be produced at the same expense on a large scale by the battery as by coal, still they were enabled readily to apply the power at any distance from its source; the telegraph might be regarded as an application of motive power transmitted by electricity. Mr. G. P. Bidder considered that there had been a lamentable waste of ingenuity in attempting to bring electromagnetism into use on a large scale. Mr. Joule wrote to say that it was to be regretted that in France the delusion as to the possibility of electromagnetic engines superseding steam still prevailed. He pointed out, as a result of his calorimeter experiments, that if it were possible so to make the electric engine work as to reduce the amount to a small fraction of the strength which it had when the engine was standing still, nearly the whole of the heat (energy) due to the chemical action of the battery might be evolved as work. The less the heat evolved, as heat, in the battery, the more perfect the economy of the engine. It was the lower intensity of chemical action of zinc as compared with carbon, and the relative cost of zinc and coal, which decided so completely in favor of the steam-engine. Mr. Hunt, replying to the speakers in the discussion, said that his endeavor had been to show that the impossibility of employing electromagnetism as a motive power lay with the present voltaic battery. Before a steam-engine could be considered, the boiler and furnace must be considered. So likewise must the battery if electric power were to become economical. Then the president, Mr. Robert Stephenson wound up the discussion by remarking that there could be no doubt that the application of voltaic electricity, in whatever shape it might be developed, was entirely out of the question, commercially speaking. The mechanical application seemed to involve almost insuperable difficulties. The force exhibited by electromagnetism, though very great, extended through so small a space as to be practically useless. A powerful magnet might be compared to a steam-engine with an enormous piston, but with exceedingly short stroke; an arrangement well known to be very undesirable.

In short, the most eminent engineers in 1857 one and all condemned the idea of electric motive power as unpractical and commercially impossible. Even Faraday, in his lecture on "Mental Education" in 1854, had set down the magneto-electric engine along with mesmerism, homeopathy, odylism, the caloric engine, the electric light, the sympathetic compass, and perpetual motion as coming in different degrees

amongst "subjects uniting more or less of the most sure and valuable investigations of science with the most imaginary and unprofitable speculation, that are continually passing through their various phases of intellectual, experimental or commercial development, some to be established, some to disappear, and some to recur again and again, like ill weeds that can not be extirpated, yet can be cultivated to no result as wholesome food for the mind."

Fifty Years Later

Fifty years have fled, and Hunt, Grove, Smee, Tyndall, Cowper, Joule, Bidder and Stephenson have long passed away. Lord Kelvin remains the sole and honored survivor of that remarkable symposium. But the electric motor is a gigantic practical success, and the electric motor industry has become a very large one, employing thousands of hands. Hundreds of factories have discarded their steam-engines to adopt electric-motor driving. All traveling cranes, nearly all tram-cars, are driven by electric motors. In the navy and in much of the merchant service the donkey-engines have been replaced by electric motors. Electric motors of all sizes and outputs, from one twentieth of a horse-power to 8,000 horse-power, are in commercial use. One may well ask: What has wrought this astonishing revolution in the face of the unanimous verdict of the engineers of 1857?

The answer may be given in terms of the action and reaction of pure and applied science. Pure science furnished a discovery; industrial applications forced its development; that development demanded further abstract investigation, which in turn brought about new applications. It was beyond all question the development of the dynamo for the purposes of electrotyping and electric light which brought about the commercial advent of the electric motor. For about that very time Holmes and Siemens and Wilde and Wheatstone were at work developing Faraday's magneto-electric apparatus into an apparatus of more practical shape; and the electric lighthouse lamp was becoming a reality which Faraday lived to see before his death in 1867. That eventful year witnessed the introduction of the more powerful type of generator which excited its own magnets. And even before that date a young Italian had made a pronouncement which, though it was lost sight of for a time, was none the less of importance. Antonio Pacinotti in 1864 described a machine of his own devising, having a specially wound revolving ring-magnet placed between the poles of a stationary magnet, which, while it would serve as an admirable generator of electric currents if mechanically driven, would also serve as an excellent electric motor if supplied with electric currents from a battery. He thereupon laid down the principle of reversibility of action, a principle more or less dimly foreseen by others, but never before so

clearly enunciated as by him. And so it turned out in the years from 1860 to 1880, when the commercial dynamo was being perfected by Gramme, Wilde, Siemens, Crompton and others, that the machines designed specially to be good and economical generators of currents proved themselves to be far better and more efficient motors than any of the earlier machines which had been devised specially to work as electro-magnetic engines. Moreover, with the perfection of the dynamo came that cheap source of electric currents which was destined to supersede the battery. That a dynamo driven by a steam-engine furnishing currents on a large scale should be a more economical source of current than a battery in which zinc was consumed, does not appear to have ever occurred to the engineers who, in 1857, discussed the feasibility of electric motive power. Indeed, had any of them thought of it, they would have condemned the suggestion as chimerical. There was a notion abroad—and it persisted into the eighties—that no electric motor could possibly have an efficiency higher than 50 per cent. This notion, based on an erroneous understanding of the theoretical investigations of Jacobi, certainly delayed the progress of events. Yet the clearest heads of the time understood the matter more truly. The true law of efficiency was succinctly stated by Lord Kelvin in 1851, and was recognized by Joule in a paper written about the same date. In 1877 Mascart pointed out how the efficiency of a given magneto-electric machine rises with its speed up to a limiting value. In 1879 Lord Kelvin and Sir William Siemens gave evidence before a parliamentary committee as to the possible high efficiency of an electric transmission of power; and in August of the same year, at the British Association meeting at Sheffield, the essential theory of the efficiency of electric motors was well and admirably put in a lecture by Professor Ayrton. In 1882 the present author designed, in illustration of the theory, a graphic construction, which has been ever since in general use to make the principle plain. The counter-electromotive force generated by the motor when running, which Hunt and Tyndall deplored as a defect, is the very thing which enables the motor to appropriate and convert the energy of the battery. Its amount relatively to the battery's own electromotive force is the measure of the degree to which the energy which would otherwise be wasted as heat is utilized as power. Pure science stepped in, then, to confirm the possibility of a high efficiency in the electric motor *per se*. But pure science was also brought into service in another way. An old and erroneous notion, which even now is not quite dead, was abroad to the effect that the best way of arranging a battery was so to group its component cells that its internal resistance should be equal to the resistance of the rest of the circuit. If this were true, then no battery could ever have an efficiency of more than 50 per cent. It was supposed in many quarters that

this misleading rule was applicable also to the dynamo. The dynamo makers discovered for themselves the fallacy of this idea, and strove to reduce the internal resistance of the armatures of their machines to a minimum. Then the genius of the lamented John Hopkinson led him to apply to the design of the magnetic structure of the dynamo abstract principles upon which a rational proportioning of the iron and copper could result. A similar investigation was independently made by Gisbert Kapp, and between these accomplished engineers the foundations of dynamo design were set upon a scientific basis. To the perfection of the design the magnetic studies of our ex-president, Professor Ewing, contributed a notable part, since they furnished a basis for calculating out the inevitable losses of energy in armature cores by hysteresis and parasitic currents in the iron when subjected to recurring cycles of magnetization. Able constructive engineers, Brown Mordey, Crompton and Kapp, perfected the structural development, and the dynamo within four or five years became, within its class, a far more highly efficient machine than any steam-engine. And as by the principle of reversibility every dynamo is also capable of acting as a motor, the perfection of the dynamo implied the perfection, both scientific and commercial, of the motor also. The solution in the eighties of the problem how to make a dynamo to deliver current at a constant voltage when driven at a constant speed, found its counterpart in the solution by Ayrton and Perry of the corresponding problem how to make a motor which would run at constant speed when supplied with current at a constant voltage. Both solutions depend upon the adoption of a suitable compound winding of the field magnets.

A little later alternating currents claimed the attention of engineers; and the alternating current generator, or "alternator," was developed to a high degree of perfection. To perfect a motor for alternating currents was not so simple a matter. But again pure science stepped in, in the suggestion by Galileo Ferraris of the extremely beautiful theorem of the rotatory magnetic field, due to the combination of two alternating magnetic fields equal in amplitude, identical in frequency and in quadrature in space, but differing from each other by a quarter-period in phase. To develop on this principle a commercial motor required the ingenuity of Tesla and the engineering skill of Dobrowolsky and of Brown; and so the three-phase induction motor, that triumph of applied science, came to perfection. Ever since 1891, when at the Frankfort Exhibition there was shown the *tour de force* of transmitting 100 horse-power to a distance of 100 miles with an inclusive efficiency of 73 per cent., the commercial possibility of the electric transmission of power on a large scale was assured. The modern developments of this branch of engineering and the erection of great power-stations for the economic distribution of electric power

generated by large steam plant or by water-turbines are known to all engineers. The history of the electric motor is probably without parallel in the lessons it affords of the commercial and industrial importance of science.

But the query naturally rises: If a steam-engine is still needed to drive the generator that furnishes the electric current to drive the motors, where does the economy come in? Why not use small steam-engines, and get rid of all intervening electric appliances? The answer, as every engineer knows, lies in the much higher efficiency of large steam-engines than of small ones. A single steam-engine of 1,000 horse-power will use many times less steam and coal than a thousand little steam-engines of one horse-power each, particularly if each little steam-engine required its own little boiler. The little electric motor may be designed, on the other hand, to have almost as high an efficiency as the large motor. And while the loss of energy due to condensation in long steam-pipes is most serious, the loss of energy due to transmission of electric current in mains of equal length is practically negligible. This is the abundant justification of the electric distribution of power from single generating centers to numerous electric motors placed in the positions where they are wanted to work.

WHAT PRAGMATISM IS LIKE¹

BY GIOVANNI PAPINI

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1. *Pragmatism can not be defined*

WHOEVER should define pragmatism in a few words would be doing the most anti-pragmatic thing imaginable. In fact, he who should try to include in a single brief phrase all the tendencies and theories which make up pragmatism would surely be doing something generic and incomplete, and the pragmatists despise nothing so much as vagueness and indefiniteness.

On the other hand, I want you, my readers, to be interested at once in the argument, and love, says Leonardo, is born, and increases with acquaintance. But how shall I proceed? I might give two or three definitions of pragmatism which I have here quite ready, and which reduce all its characteristics and elements to a single one, but I do not feel that I can recommend my wares.

I could tell you, for example, that pragmatism is nothing but "*a collection of methods for augmenting the power of man,*" but you could answer that even a manual for tunnel builders would then form a part of pragmatism. Another pragmatist could, on the other hand, assure you that his doctrine is founded upon preoccupation with the future (consequences, previsions), and that therefore it might also be called *prometheism*. You would promptly ask him if books of meteorology, or manuals of prophecy from dreams, or the Utopias of the reformers, form parts of pragmatism.

It would be worse yet if any one should undertake to say that the theory of pragmatism lays stress upon the practical and, in the selection of its doctrines, substitutes the criterion of utility for that of truth. This definition contains much that is true, but one must examine closely what is meant by the practical and by utility, in order that they may gain an undeniable meaning. In fact, what theory is there whose originator does not claim for it practical consequences? What theory would be completely unutilitarian? Theories have a certain sort of utility which coincides with their truth, as, for example, it is commonly useful to hold theories which bring about true previsions. And there is another sort of utility in contrast with this, as, for example, the moral enthusiasm which a belief might give us, even though it were entirely absurd.

¹ Translated by Katharine Royce.

These definitions might be continued, but you would probably arrive at the conclusion that pragmatism, instead of being something new, embraces a vast number of already existing things, and that it is already accepted and practised, consciously or not, by all thinking men.

In this, however, you would be wrong, because, seriously, pragmatism contains new things, and if it is practised by many, it is not recognized or accepted by all. The blame lies with the definitions, since they must not or can not be made as long as books. For definitions, reduced to a single phrase attempting to give an explanation and résumé of the whole, end at best by failing to make really clear that of which they treat. Oftener still, they give rise to embarrassing equivocations and false representations. In order to show the novelty and specific nature of any doctrine whatever, we must come down from the universal to the particular, and fill such large abstract terms as potentiality, actuality, future, etc., with the wealth of special theories and of concrete facts. Without realizing it, I have already given you an elementary first lesson in pragmatism.

2. *What may be expected of Pragmatists*

As soon as I have begun one task, another lies before me. One of the maxims dearest to the pragmatists is this: that the meaning of theories consists entirely in the consequences which their followers may expect from them. To affirm anything actually means this: I foresee that certain things will follow, or that I shall do certain things.

Now apply this maxim to the definition of pragmatism itself, and ask me: What actions or beliefs may be expected from a thinker who is a confessed pragmatist?

That is soon said. These expectations relate almost wholly to his *choices* in the world of thought. That is, we can foresee what things he will love and what things he will hate; what problems he will consider important, and what ones he will reject as useless; what will be his sympathies and antipathies in the world of ideas and of men.

He will seek in every way *not to concern himself* with a great part of the classical problems of metaphysics (in particular with the universal and rationalistic explanation of the sum total of things), which are for him non-existent and senseless problems. On the other hand, he will concern himself strenuously with *methods* and *instruments* of knowledge and action, because he will be sure that it is far more important to improve or to create methods of obtaining exact previsions, or of changing ourselves or others, than to sport with empty words around incomprehensible problems.

His sympathies will be with the study of the particular instance; with the development of prevision; with precise and well-determined

theories; with those which serve as the best instruments for the most important ends of life; with conciseness, with economy of thought, etc.

Naturally he will have an antipathy for all forms of monism; for all universal phrases which signify nothing or too much: for obscure babblings about absurd and inconceivable questions. He will distrust, I say, the pretended evidence and intuitiveness of principles; the faith in a sole and changeless truth; all agnostic theories which make what lies beyond sense a synonym of the unknowable. He will reject all that refuses to change or to adapt itself, all that claims to rule in the name of the divine right of the absolute. He will show no respect or subservience to the famous "reality" of the ordinary man and to the *terre à terre* of the empiricist.

That is to say, the pragmatist scorns those doctrines which pretend to explain the world by means of three or four mysterious phrases in the name of some unique principle. The pragmatist has an equal contempt for those doctrines that humbly cling to brute facts, as experience gives them to us, without trying to extend them into theory (the narrow empiricism and utilitarianism of so-called common sense), or into practise (the ethical evolutionism of "resignation to the laws of nature"). Instead we see the pragmatist kindled by a certain spirit of enthusiasm for all that shows the complexity and multiplicity of things; for whatever increases our power to act upon the world; for all that is most closely bound up with practise, activity, life.

Now if all these characteristics fail to define with sufficient fullness and precision what pragmatism is, yet they may give some idea of its tendencies.

But I can do something more to give precision to these ideas: that is, I can show in what points pragmatism *does not resemble* preceding systems of philosophy.

3. *Pragmatism is not a "Philosophy."*

Pragmatism differs above all from other philosophies through the simple fact that it is not a philosophy, if by philosophy you mean a system of metaphysics, a system of the universe, a *Weltanschauung* or any such matter. The pragmatist, in so far as he is a pragmatist, does not profess idealism rather than materialism, does not believe in the doctrine of creation rather than in that of emanation. For him, *comprehensible* metaphysical theories (and they are not many), can only give rise to *moral* consequences that differ—for the practical and experimental expectations are the same for all. This implies that the most rampant idealist and the timorous materialist would avoid in just the same way an automobile which was about to throw them down; while the beliefs of the former would favor certain moral ideals,

such as pride, nobility, the platonic dream of a world-builder, etc., more than those of the latter would.

For the pragmatist, then, no metaphysical hypothesis contains more truth than another. He who feels the need of one may choose it according to his purposes and his taste in ideas, but he should not greatly flatter himself that his hypothesis can be recognized as the most solid and certain, the best proven and demonstrated.

Pragmatism contains, therefore, no metaphysics, either open or implied. For it, the different theories of the world, properly understood, are but diverse ways of affirming the same commonplace facts, and their value consists solely in their form side, which may be more or less suggestive, more or less favorable to certain aims and preferences of our minds. For the pragmatist, metaphysical theories are facts amongst other facts, and for him the thing that matters is the power of foreseeing the varieties of behavior of the different men who believe in those theories.

From what I have said, it will perhaps seem clear that pragmatism is really *less a philosophy than a method of doing without philosophy*. On the one hand, by striving against problems devoid of sense, such as metaphysics, monism and the like, it diminishes the field of action of that which, historically speaking, is called philosophy; and, on the other hand, by inciting men to act more than to talk, to alter things rather than to contemplate them, to force things actually to exist in a definite way, instead of asserting that they already do so exist, it enlarges the field of action at the expense of pure speculation. Pragmatism would seem to be, then, not only something different from philosophy, but even hostile to metaphysics taken in the traditional cosmological sense.

And the differences do not end here. Another equally important distinction is the *pluralistic* character of pragmatic theories, in contrast with the unity and formal organization of systems created or elaborated by one single mind. A great many do not yet perceive that there *is no such thing as pragmatism*, but that there are only *pragmatic theories*, and *thinkers who are more or less pragmatic*. Let it be understood that among the theories of these thinkers there are affinities and points of contact among their tendencies, otherwise the common adjective would not be justified. But that does not do away with the fact that pragmatism is a *coalition* of theories coming from various sources and temperaments rather than a handsome system sprung from the brain of a single philosopher, or from a homogeneous and well-organized school. If you compare its somewhat chance formation, to which so many men and countries have contributed with rational and well-constructed bodies of thought, such as determinism in the works of Spinoza, absolute idealism in those of Hegel, evolution in those of Spencer, the difference is most plainly evident.

The scattered state of the ideas which have been grouped together under the name pragmatism makes it impossible to find a thinker who is a pragmatist from head to foot. Some people are, even though unconsciously, pragmatical on some points or on certain sides, while they are not pragmatical, or are even anti-pragmatical, on other sides. This spirit of liberty, this freedom from rigidity which the pragmatists have discovered in the sciences exists also in their own doctrine.

4. *Pragmatism is Different from Positivism*

In making this rapid survey of the differences between pragmatism and the philosophies, I have purposely left positivism on one side, because the question of its relation to pragmatism is far more complicated.

In fact, there are those who maintain—either through timidity or ignorance—that pragmatism is nothing but a version, or a trivial revision, of what is known as positivism, or agnosticism. Naturally there are those who say that it is a perfecting, others who say that it is a deterioration of positivism. Mario Calderoni, although he asserts that the name pragmatism expresses “really, an advance upon the system of positivism,” yet affirms the “fundamental identity” of the two doctrines. In fact, he sees nothing more in the struggle of Peirce against meaningless questions than a simple continuance of the strife of the positivists against metaphysics. Upon this point I do not agree with Calderoni, and I marvel that such a passionate lover of distinctions should not see what differences there are between the two doctrines.

There are two points in which they seem to agree: the importance of prevision, and the rejection of futile and absurd questions. But even concerning these two points there are differences, not to mention others which we shall examine later.

In fact, pragmatism does not consider prevision merely as opening the way to practical applications, or as an aid in verifying theories, but also as a means of *definition* and *interpretation* of the theories themselves. In this case, therefore, such prevision forms a completely new addition to the positivist's method.

Pragmatism, like positivism, condemns and discards the absurd and empty questions which form so large a part of metaphysics, but it does not discard them because they are *insoluble*. That is to say, nearly all the positivists are agnostics, and say that the human mind *can not succeed* in solving these problems. The pragmatists, on the contrary, are all anti-agnostics, and maintain that it is not true that those problems are too *lofty* for our intelligence, but too *devoid of sense*, too stupid, and that their unwillingness to busy themselves with

such matters is not a proof of the impotence, but of the power of our mind. The positivists repudiate metaphysics, but as they do not sufficiently explain *why* they do so, they leave open a way whereby the exiled problems may return. And thus a still graver thing happens, for the lack in their theories, of a sufficiently profound analysis of the methods of science and of philosophy, gives the metaphysical spider a chance to spin its web once more even within themselves and in their own thought. This may be seen in even the best representatives of positivist methods, for these, while raising their voices upon all occasions against vain and empty metaphysics, yet do not perceive the poor and feeble metaphysics in their own books and discussions. Agnosticism, monism, materialism, evolution, which are almost always associated or confused in the minds of the positivists, are metaphysical doctrines which presuppose in their turn metaphysical premises. Agnosticism implies the belief in a world more real than ours. Monism appeals to universal and unthinkable conceptions. Evolution supposes a sort of providential plan of the universe, and so on. Positivism, then, is only *anti-metaphysical in words*, while pragmatism is *anti-metaphysical in substance*.

And the differences do not end here. There are in pragmatism at least three tendencies which in agnostic positivism do not exist at all, or at best only in the germinal state.

First of all is the principle of the *economy of thought*, traces of which may more easily be found in Ocean and Leibniz than among the positivists. Secondly, the resurrection of the Baconian axiom "knowledge is power," that is, the demonstration of the part played by the idea of power and the possibility of power in our beliefs and theories. Finally, the *emancipation of thought, both from immediate facts and from pure rationalism*. Both are shown in pragmatism, not only by its theories about the free "creation" of facts, and of hypotheses in science, but also by its views concerning the non-necessity, for deduction, of the premises being "rational." That is to say, its willingness to start from absurd or fanciful hypotheses, in building up new theories and new sciences. It seems to me, then, that this is enough to justify the separation of these two lines of thought under distinct names, the more so since it can be shown historically that the differences between positivism and pragmatism are much greater than those which existed between positivism and the earlier so-called "English philosophy." Pragmatism may indeed continue on certain lines the work of some of the best positivists, but it may claim, when closely considered, to be really made up of differences from positivism. It would be hard to differ more than that!

5. *Why it is Good to be a Pragmatist*

After all this talk my readers probably begin to see what it means to be a pragmatist, but it would not surprise me to hear some one say: Then, since it seems the pragmatists prefer theories that are of some use, tell us, please, what is the use of being a pragmatist.

The answer, after what I have said, is not difficult. The spiritual gains of one who is or becomes a pragmatist are not to be despised. The first is a *gain of time*, for the pragmatist gives a definitive *quietus* to the so-called "insoluble problems," the pretended "enigmas of the universe," which are merely non-existent or ill-stated problems that become soluble when stated in the pragmatic way. The time thus saved can be used either in the study of other problems, or in the practical application of theories that have been already verified by experience.

The second gain is the *mental stimulus* given by the consciousness of our human control over scientific conceptions, and over our own minds, and by the feeling of the plasticity of truth and of the opening of ever-wider spheres of possibility offered to the deductive imagination, and to the powers of the human soul over the universe.

This economy of time and strength and this increase of satisfaction and enthusiasm will suffice, I should think, to content those who have any intention of becoming pragmatists. If these do not suffice I will point out other advantages. Pragmatism having the characteristics of a *thing not yet finished*, not completely worked out, not fixed and crystallized, can therefore offer to him who turns to it the possibility of developing and transforming it, that is, of being not merely one of its followers, but at the same time one of its creators. Pragmatism thus offers the advantage of not being in itself a metaphysic, but of permitting the esthetic or moral enjoyment of possible or actual metaphysics.

6. *Who will become Pragmatists?*

There is one last question that could be asked. Who are the men who most readily become pragmatists? Is it possible to predict what classes of minds are the most disposed to receive the teachings of pragmatism?

In order to answer, I should perhaps have to build up the psychology of the pragmatist type. For theories, even the purest and abstractest, have their actual ground and source in biological needs, and in the deepest sentiments of the general human race, or of particular exceptional persons.

This conception of Nietzsche—which the pragmatists have taken up and unfolded—of the vital and moral sources of "pure thought," so-called, shows us, when applied to pragmatism itself, the three groups

of sentiments which are to be found hidden in the souls of the pragmatists. The first group is that of our *vital sentiments*, that is, of our instinctive desires for a larger and richer life, for more extended power. Our love of the concrete, of real and particular things, comes in here, as well as our fondness for dreams that "come true"; also our hatred of useless words, and of dreams foisted upon reality, that neither let us contentedly accept it, nor enable us to alter it.

The second group may be called the *pessimistic sentiments*. These are shown in the tendency to wish to change all existing things, facts and theories. Another manifestation of this is a certain aversion to anything that comes to us claiming to be already complete, and forces itself upon our acceptance, whether it call itself scientific hypothesis or law of nature.

The third group, on the contrary, is optimistic in its character. It consists in *sentiments of pride*. These are shown in our honorable reluctance to accept things ready-made, instead of making them for ourselves; in our unwillingness to receive our intellectual inheritance without right of appeal or revision. They are also shown by the dislike of submission to what men call the inevitable, the unchangeable, the eternal, and by the proud hope of being able to change existing things by means of simple spiritual force.

To come down from this hypothetical psychology to a more exact forecast, I believe, in general, that all those who think in order to act, who prefer provisional truths that work to over-abstract terms, however intoxicating, may be in sympathy with pragmatism.

Excluded beforehand, consequently, are all pedants devoted to fixed formulæ, all systematizers who see the world under the despotism of a symbol; all lovers of immutable truth, of pure reason, of transcendental conceptions, in a word, all conservatives of a rationalistic complexion. But there are, in particular, two classes of minds that seem to me destined to form the bulk of the pragmatist army. I mean practical men and Utopians. The first, because they find in pragmatism the theoretical explanation of their scorn for questions that have no sense or practical import, and of their sympathy with all that is clear, potent and unencumbered. The second, because they find in pragmatism suggestive points of view that encourage them to imagine and to hope extraordinary things. The ideas of pragmatism about absurd hypotheses, about imaginary sciences, about the influence of the will upon belief, and of belief upon reality, seem made on purpose to stimulate the poets and dreamers of the world of thought. Thus pragmatism, in this sole point resembling the Hegelian dialectic, succeeds at last in reconciling opposites.

THE PROBLEM OF AGE, GROWTH AND DEATH

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IV. DIFFERENTIATION AND REJUVENATION

Ladies and Gentlemen: In order to present the subject of this evening, I will take a few brief moments at the beginning to review the results reached in the previous lecture. In the last lecture I spoke of the phenomena of growth, and endeavored then to make clear to you what I consider the fundamental conception of this study—that the decline in the growth power is extremely rapid at first and slow afterwards. This change in the rate of growth is of course due to things in the animal body itself. It is a logical conclusion for us to draw that if we are to study out the cause of the loss of growth power, we should do it rather at that period of development when the change in the rate of growth is most rapid, for then we should expect those modifications to exhibit themselves most clearly because the magnitude of cause is likely to be proportionate to the magnitude of result, and when the decline is most rapid, then we must expect to find the alterations which cause that decline in the organism to show themselves most conspicuously. You will remember, further, that we spoke of growing old as being a much more complicated question than one of growth alone, and that there occur, as the years advance, changes in the structure of the body. It is convenient to use one collective term for all these phenomena of becoming old, and that term, established by long usage, is *senescence*, the becoming old. What, therefore, we have to search for at present is a cause, a proximate cause at least, of senescence. In order to make the view I am to bring forward this evening quite clear to you, I must first of all take advantage of your kindness and recapitulate briefly what I said in regard to cells, for you will remember that the cell is the foundation and unit of organic structure. With your permission I should like to recall more exactly to your minds what I said of the cells by having thrown upon the screen the slide which we saw before and which we used as an illustration of the cell. Here is the picture. Above we see the typical cell from the oral epithelium of the salamander, and you remember in the center this more conspicuous body with a granular and reticulated structure which we called the nucleus, and surrounding it is this mass which we called the body of the cell, or the protoplasm. Here is an-

other condition of a cell of the skin of the salamander in which the nucleus presents a slightly different appearance. Here also we have quite a body of protoplasm about the nucleus. Every cell consists of these two essential and fundamental parts, the nucleus and the protoplasm. Now the conclusion to which I shall gradually bring you by

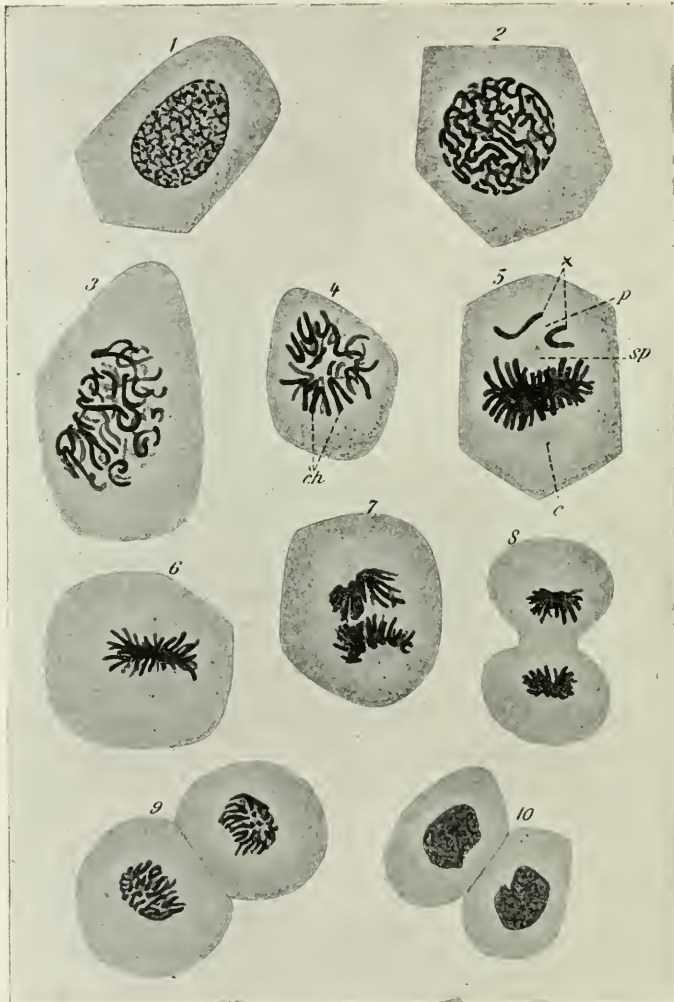


FIG. 39. CELLS FROM THE MOUTH (ORAL) EPITHELIUM OF THE SALAMANDER.

the facts to be laid before you this evening is that the increase of the protoplasm is the thing which is to be regarded as the explanation of senescence. Though protoplasm is the physical basis of life, though it is the actual living substance of the body, its undue increase beyond the growth of the nucleus changes the proportions of the two, and that change of proportion seems to cause an alteration in the conditions of

the living cell itself, and that alteration I interpret, as I shall explain more accurately later, as the cause of senescence, as the fundamental cause of old age. This slide also shows to us the early development of the cells through those phases which result in the multiplication of them. The nucleus changes in appearance and becomes a very different-looking structure. These changes I need not now go through again. Suffice it to say that after the complicated alterations have completed their cycle, we get in the place of a single cell, two, and

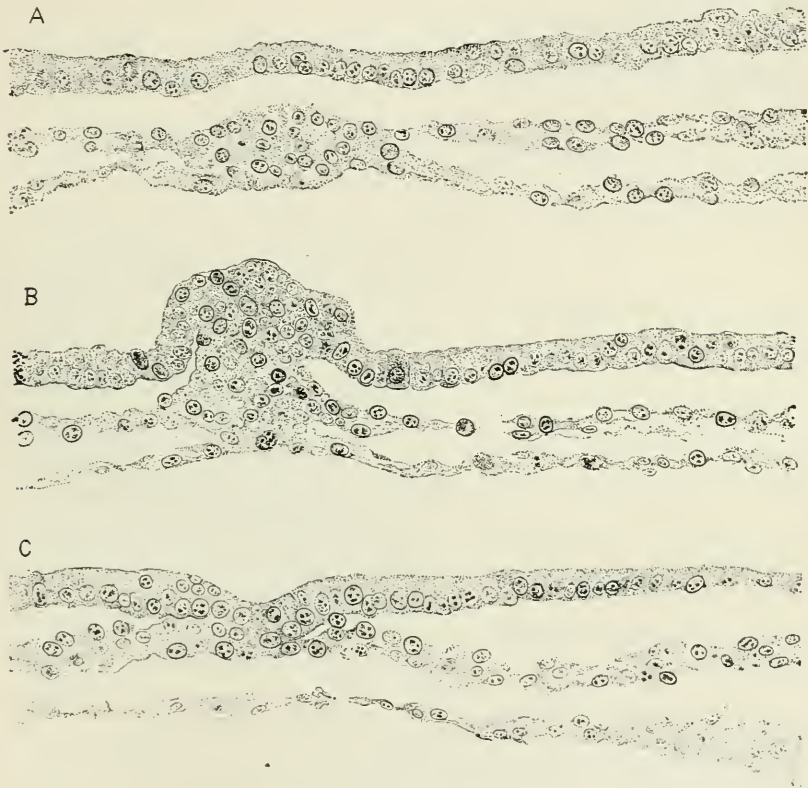


FIG. 40. THREE SECTIONS THROUGH A RABBIT EMBRYO OF SEVEN AND ONE HALF DAYS.

each has its own nucleus, and each its own protoplasm. Notice here that the two cells which finally result are smaller than the original cells from which they sprang. These are by no means imaginary pictures, but accurate microscopic drawings from real cells of the salamander skin. The two cells which are thus produced from one parent cell are characterized by their smaller size, and this smaller size applies not only to the cell as a whole, but likewise to its nucleus. After having been thus reduced in size, the nuclei and the cells will both expand, and soon the daughter cells will return to the mother dimension and be as large as the parent cell from the division of which

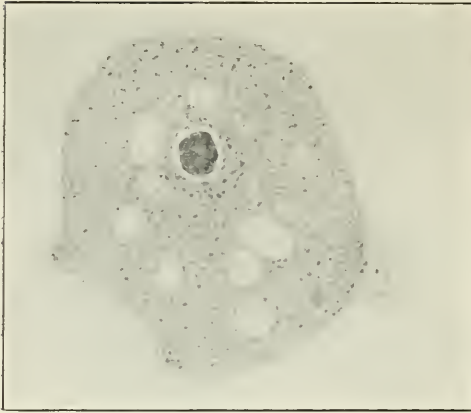


FIG. 41. *Amoeba coli*, HIGHLY MAGNIFIED. Drawn from a cover-glass preparation from a twenty-four hour culture.

These represent slices through a very young rabbit before any of the organs of the rabbit have begun to develop. We can see here clearly the nuclei, as I pointed out to you before, nearly uniform in structure, and you notice that the protoplasm around each nucleus is quite small in amount. If you will recall the previous picture of the skin of the salamander, upon the screen a moment

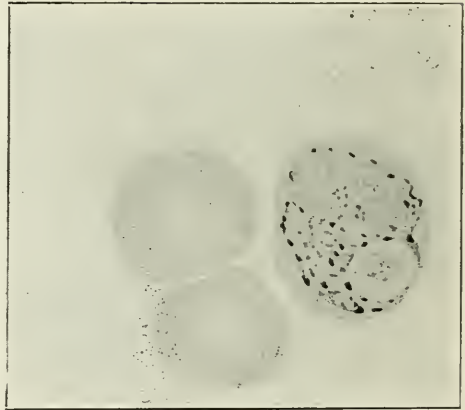


FIG. 42. TERTIAN MALARIAL PARASITE. Two human blood corpuscles alongside and drawn on the same scale.

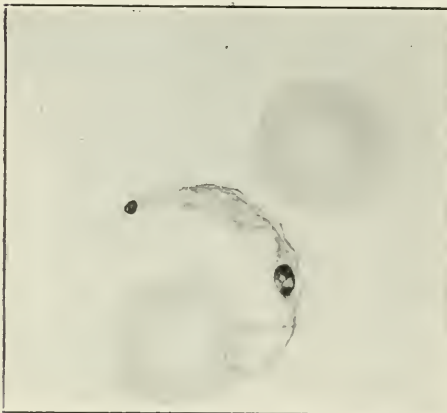


FIG. 43. *Trypanosoma Lewisi*, from the rat's blood with two blood corpuscles alongside drawn on the same scale.

they arose. There is thus, we learn, the constant fluctuation in the size of cells, a fluctuation in their dimensions accompanying the process of cell division. Presently we shall have more to say in regard to this matter of the change in the cell in size. The next picture (Fig. 40) which I want to recall to you is one which we also had in an earlier lecture.

ago, you will realize immediately, in comparing the two, that in these young cells the proportion of the protoplasm to the nucleus is very small. That is again one of the fundamental facts to which we shall recur in a moment. I wanted to show you this picture in order to revive in your minds the conception which I endeavored to give you before of the undifferentiated tissue, where the cells have nuclei pretty

uniform in appearance and in size, each with its little mass of protoplasm about it, and this protoplasm appearing in all the cells under microscopic examination very much the same. We can not in this stage of development say of a given cell that it represents any special structure, by which, if we saw it isolated under the microscope, we could determine from what part of the young embryonic body it was derived. When we see a cell from the adult we can determine its origin with certainty by its microscopic appearance alone. As development progresses, the simple condition of the cells is gradually obliterated, but we find another condition arising which we call the differentiated one. Differentiation is a process which goes on in the body as a whole, but of course it is also a function of each individual cell. We can see something of the process of differentiation if we study the unicellular organisms, those creatures, each of which is complete in itself, although it consists of but a single cell, not of countless millions of cells as we do. The picture (Fig. 41) which I have chosen to throw upon the screen is one which I think might have an additional interest to you, for it is a photograph from the living cell known as the parasite producing dysentery. Its scientific name is *amaba coli*. It is a photograph from life. Here vaguely in the center, marked with a finer granulation, and some of the darker spots in it, we can distinguish the nucleus: here is the outline of the protoplasm of this cell, and in it are included some particles of food which this protoplasmic body has absorbed for purposes of digestion. This is a unicellular parasitic organism with scarcely any differentiation of its structure. The next of the slides shows us again another of these parasitic simple organisms. The figure here to the right of the field of view is the one which should especially attract your attention. The other two bodies near it are blood corpuscles, human blood corpuscles. The organism in this case is the one which causes malarial fever, and it is in a particular stage of its development; that which we distinguish as the tertian malarial parasite is the one here represented. You can see in this case also the outline of the nucleus, surrounded by the protoplasm—the whole thing only a little bigger than a single human blood corpuscle. Here also we note the absence of differentiation. Another stage of this same tertian malarial parasite is shown next. This I have projected upon the screen because it illustrates more clearly than the other the nucleus and the small amount of protoplasm about the nucleus. The malarial organism is one of great vitality, capable of enormously rapid multiplication, and it undoubtedly owes that faculty to its constitution, to the relation between the nucleus and the protoplasm. I will now show you another picture of parasites—one form of which, in a related species, occurs in man. This particular form is one which occurs in the rat and is called the *Trypanosoma*. You can see that the body, instead of being a small and simple struc-

ture, has elongated, acquired a peculiar form, and here in the interior are lighter and darker spots. These do not show very clearly in the picture, because it is from a photograph of a living specimen under the microscope. The lighter and darker spots correspond to the details in the structure of the organism. Here is the tail of the organism, twisted, as you see, and in life capable of being bent. The movement of the animals in the natural fluid in which they are suspended is quite active. Alongside are some blood corpuscles, the figure, as you see, is magnified about the same as the one of the malarial parasite which I showed you a few moments ago. The next slide exhibits an

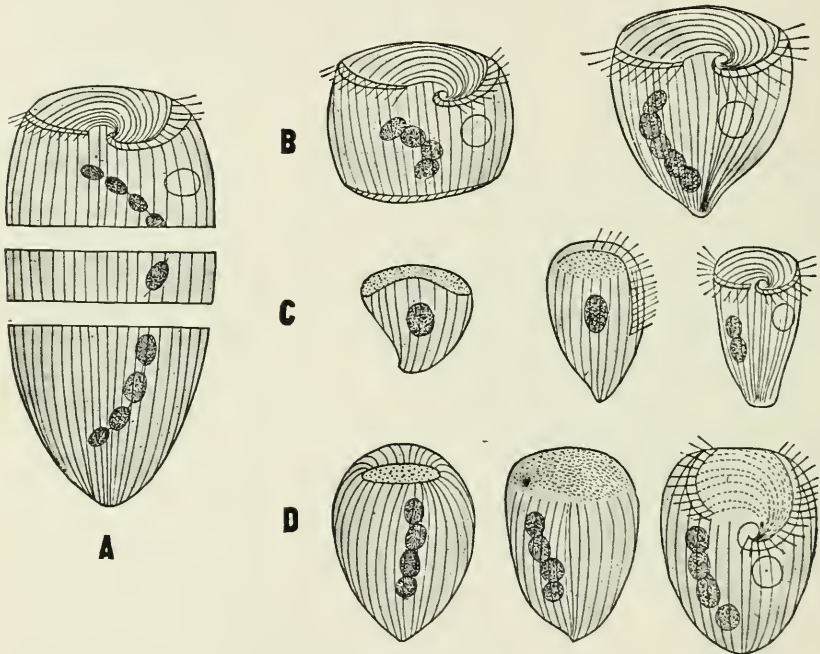


FIG. 44. *Stentor ceruleus*. A, cut into three pieces; B, regeneration of the first piece; C, of the middle piece; D, of the posterior piece. After Gruber.

organism which swims free in the water, and is pretty well shown in this figure. It is called the *Stentor*. Here the chain of beads represents the nucleus. Upon the surface of the body there are fine lines indicating superficial structure. At this point there occurs what we call the mouth. Over the rest of this minute organism there is a thin cuticle, but at the mouth the cuticle is absent, and the protoplasm is naked or uncovered so that food can be taken in. There are bands of hairs showing coarse and stiff in the figure but capable of movement, and with the aid of those vibratile hairs, or cilia, the organism can swim about in water. Here is another internal structure, the vacuole; obviously in an animal like this we no longer have simple protoplasm

alone, but the protoplasm in the interior of the cell has become in part changed into other things. Here then within the territory of a single cell we have differentiation. If now in these unicellular organisms we study both the protoplasm and the nucleus, we learn that most of these modifications which are so conspicuous upon microscopic observation are due to changes in the protoplasm. It is the protoplasm which acquires a new structure. In the nucleus, on the contrary, we find perhaps a change of form, minor details of arrangement by which one sort of nucleus, or one stage of the nucleus, can be distinguished from another, but always the nucleus consists of the same fundamental constants. There is the membrane bounding it; there is the sap or juice in the interior; the network of living threads stretching across it; and here and there imbedded in and connected with this network are the granules of special substance, which we call chromatin. These four things exist in the nuclei and are apparently always present, and there is usually not to be seen in the nucleus anything of change comparable, in extent at least, with the change which goes on in the protoplasm—on the other hand, the protoplasm acquires items of structure which were totally absent from it before. The nucleus rearranges its parts rather than changes them. This is a very important fact, and shows us, if we confine our attention even to these little organisms only, that the differentiation of the protoplasm is *quantitatively* the more important of the two—the differentiation of the nucleus the less important.

We can now turn from a consideration of these lowest organisms to the higher forms, among which we ourselves of course are counted, in which the body is formed by a very considerable number of cells. Again I should like to take advantage of your kindness and show you some of the pictures we have already reviewed, in order to utilize the features which they show as illustrations of the fundamental principle that the conspicuous change is in the protoplasm. Here we have nerve cells. In the first two photographs are represented two isolated nerve cells, to show their shape. They have been colored by a special process so dark that the nucleus which they contain in their interior is hidden from our view; it is of course none the less there. This dark staining enables us to trace out the shape of these cells very clearly, and you can see that instead of being round and simple in form they have their elongated processes stretching out to a very considerable distance; these processes serve to catch up from remote places nervous impulses and carry them into the body of the cell, and thus assist in the work of nervous transmission. The elongation of these threads is, as you see, adapted, like the elongation of a wire, to long-distance communication. Here are two other figures which represent nerve cells treated by a different process, and again artificially colored. But the color in this case has attacked certain spots in the protoplasm,

consequently we see that the protoplasm around the nucleus in both of these figures is no longer simple and uniform, but contains these deposits of dark-colored material. Here are other nerve cells: the one

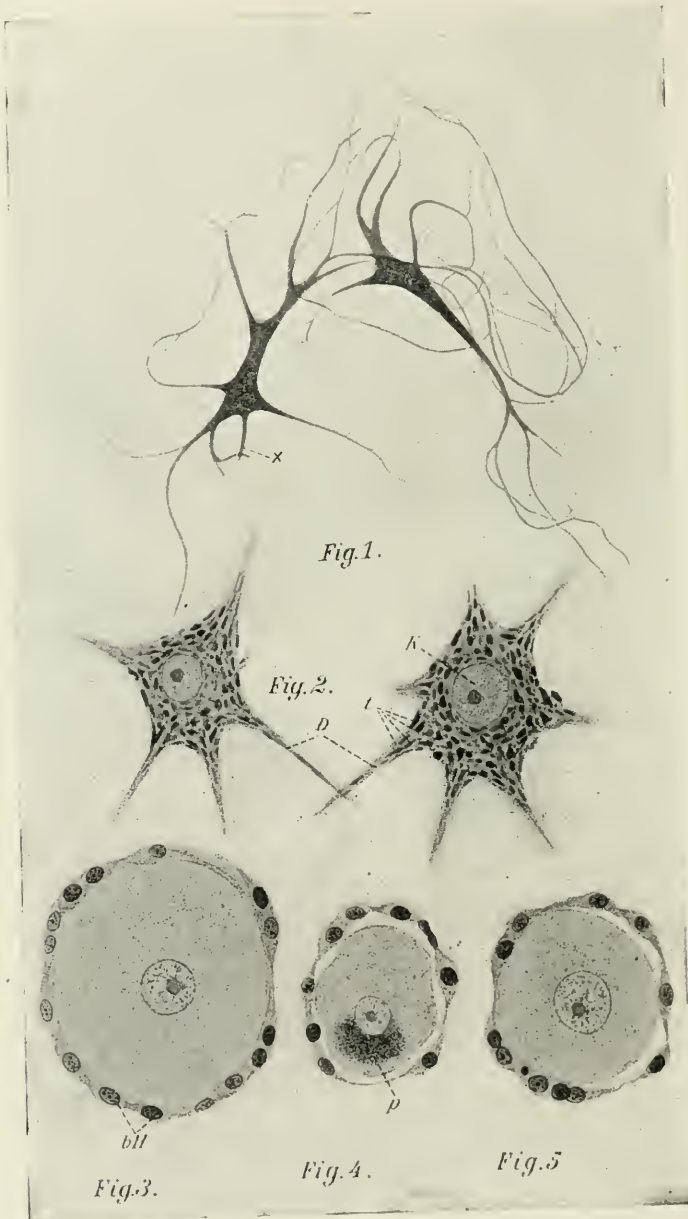


FIG. 45. VARIOUS KINDS OF HUMAN NERVE CELLS. After Sobotta.

in the center shows you the accumulation of pigmented matter in the protoplasm; again an index of a change and lack of the previous uni-

formity replaced by diversity in the composition of the various parts of the single cell. This figure shows us more clearly the principle of structure of a nerve cell, for here we have the central body of the cell composed of protoplasm with its nucleus in the middle and a small spot in the center of the nucleus, and these long branching processes running out in all directions which can take up nerve impulses from other similar or dissimilar cells, as the case may be, and carry them to the central body. To carry the message out there is typically but one process, which is different in appearance from the other processes which carry the impulses in. The latter are branching and are therefore called the tree-like or dendritic processes. Here is a single process like a long thread to carry the impulses away, and which

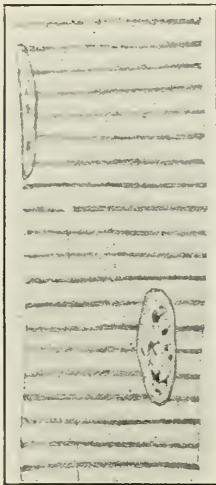


FIG. 46. PART OF A HUMAN MUSCLE FIBER.

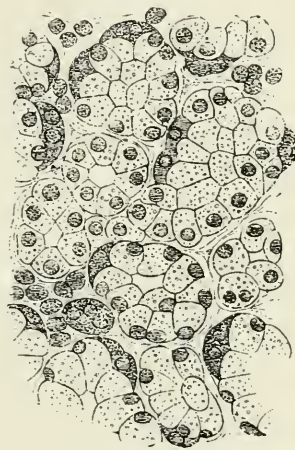


FIG. 47. SECTION FROM AN ORBITAL GLAND.

is called the axon of the nerve cell. In this case the modification of the shape of the cell has adapted it to the better performance of its functions. Notice also in these cells the enormous increase in the amount of protoplasm as compared with the nucleus. In the young cell of the rabbit germ, of which I showed you several illustrations a few moments ago, we had very little protoplasm for each nucleus, but here the protoplasm has many, many times the volume of the nucleus, and this is a relatively old cell.

Next let us look again at the figure of the striated muscle fiber, which you may recall from the second lecture, so that it will suffice if your attention is again directed to the oval nuclei, and to the lines stretching crosswise on the muscle giving it a "striated" appearance. You remember, doubtless, that such fibers are the ones which enable us to make voluntary motions. Originally each fiber was a set of

cells, and the cells had some protoplasm, but, gradually, as development progressed, there appeared in them longitudinal fibrils different from the protoplasm, and the fibrils also created ultimately the appearance of cross lines on the fiber. It is the fibrils which perform the muscular contractions. It is not the original unmodified protoplasm, but the modified or differentiated muscular cell which is capable of voluntary contraction.

The next picture (Fig. 47) shows us clearly and strikingly how much the differentiation may vary. We have here another type of differentiation. These are gland cells; we can see here, as I pointed out to you before, the material in the form of granules, which is to produce the secretion from these gland cells. This is an orbital gland, and here are the cells, which are very much smaller because they have discharged their secretion. Three of the cells are represented separately. The first shows us a cell full of the material which is to be discharged and is to form a part of the secretion of the saliva. The second is a cell which has partly lost its accumulated material, and the third is one which has discharged it almost completely, so that it has become very much reduced in size. We learn from such structures as these that the size of cells may vary also according to their functional condition. We have here a similar gland. This is sometimes called the salivary gland of the intestine, better termed the pancreas. Here we can see for each of these cells a nucleus and a body divided into two parts, a darker portion around the nucleus and a lighter part with little granules in it, which represents the accumulation of material which is to form the secretion. When the cells have discharged their secretion, they, like the cells in the salivary gland, are found to have diminished in size and become very much smaller indeed than they were in their earlier state when charged with the zymogen destined to be given out. In this case also we have an illustration of a functional variation in the size of the cells. This ends the series of pictures which I wanted especially to show to you as illustrating the changes of the cells as their differentiation progresses. We can see in the bodies of the cells the changes which have occurred.

Here is a picture which teaches us one thing more about these cells. Notice the scattered nuclei, each surrounded by protoplasm, completing the cell. The protoplasm of each of these cells is connected across with the protoplasm coming from another, so that the whole set of cells forms an irregular protoplasmic network. Now in the spaces between these cells are fine lines. These represent delicate structures which we call connective tissue fibrils, which have a mechanical function. By their tensile strength, their power to resist and pull, they give a certain supporting power to the tissues. Our picture represents one of the tissues which support and connect other portions of the body. Now the fibrils apparently lie entirely disconnected from

the cells, but a more careful study of the history of the connective tissue has revealed the very interesting and instructive fact that the fibrils, now separate from the cells, arose by a metamorphosis of the protoplasm of the cells—that they are first formed out of some of the protoplasm of these cells, then split off from them, and come to lie in the intercellular regions, so that here we have another type of cell differentiation brought to our notice, one in which the product is separated from the parent body to which it owes its origin. Now you will perceive immediately, if you recall the series of pictures which have just passed before us on the screen, very great differences in the types of differentiation which occur in the body, and had we time we might find a very much larger range easily to be represented before us.



FIG. 48. EMBRYONIC SYNCYTIUM FROM THE UMBILICAL CORD OF MAN; *c, c*, cells; *f*, fibrils.

In the second lecture a picture was projected upon the screen, which showed motor nerve cells of various animals. You will recall that I directed your attention to the fact that the largest animal, the elephant, has the largest cells, and the smallest animals, the rat, the mouse and the little bat, have the smallest ones. But let me point out to you that the question of the size of cells is exceeding complex, and that in studying it we have to exercise a great deal of caution. We know that, with the exception of the nerve cells and to a minor degree with the exception of the muscle fibers, the cells in each animal are more or less uniform constants in size. The cells of different organs differ somewhat from one another. A single organ may have in its different parts typical sizes of cells, but each of these kinds of cells has its definite dimensions. When one animal is larger than another,

it has more cells. Now it is a very important fact for us that animals have a more or less constant size of their cells. They do not differ from one another by a difference in the size of their cells; the bigness of an animal does not depend upon the size, but upon the number, of its cells. We can, therefore, in studying the changes of size, to which I shall next direct your attention, omit altogether these details, and speak of the cells in a general way safely as having a certain uniform or standard size. This will save us a great deal of time, for we learn, as we study cells, that their size increases with the age of the animal. The animal, when it is young, has cells with a small amount of protoplasm. And that, you will perceive from the pictures which have been thrown upon the screen, is an absolutely necessary corollary of the discovery that differentiation is mainly a function of the protoplasm. If there is to be a large degree of differentiation it is necessary that the quantity of protoplasm in the single cells should be increased, so that there may be the raw material on hand out of which the differentiated product can be manufactured. If there is not such a preliminary increase of the protoplasm, then the differentiation can not occur. In order that perfection of the adult structure should be attained, it is necessary that the mere undifferentiated cells, each with a small body of protoplasm, should acquire first an increased amount of protoplasm, and that then from the increased protoplasm should be taken the material to result in differentiation, in specialization.

An undifferentiated cell performs all the fundamental functions of life. An amoeba, or any unicellular organism such as I have presented to you upon the screen, does everything which is indispensable to life. It takes food; it forms secretions and excretions; its activity depends upon chemical alterations going on in the food in the interior of its body: it is capable of sensation and of locomotion. It is probable that every living cell has all of these fundamental properties of protoplasm. When a cell becomes differentiated, however, though it does not necessarily give up any of its vital properties, it becomes different from other cells because one of its properties is made conspicuous. And in order to acquire that conspicuousness, that excess of development of one function of the cell, a modification in the structure is necessary. The apparatus in the interior of a cell to produce the exaggeration of the function must be developed, so that to effect the complex physiological machinery of the adult body, this differentiation, of which I have so often spoken, is indispensable. A nerve cell carries on all the vital functions, but it has in addition a special series of modifications of its protoplasm which enable it to accomplish the transmission of the nervous impulses with greater efficiency than ordinary protoplasm can do, probably at a higher speed and with a more perfect adjustment of communication between the various parts of the body than is possible with any machinery of pure protoplasm. So

too, the glands have cells which are especially capable of elaborating chemical substances which, when they are poured out, accomplish the work of digestion, for instance. But these cells are likewise alive in all their parts. They have all the fundamental vital properties, but there is this tremendous exaggeration of the one faculty, and that involves an alteration so great in the protoplasm that we can see it with the microscope; the microscope affords us a perfect demonstration of differentiation, which we can correlate with the function.

The primary object, therefore, of all differentiation is physiological. The higher organism, with its complex physiological relations, is something really higher in structure than the lower organism. The term "higher" in biology implies a much more complex interrelation of the parts, a much more complex relation of the organism to the outside world; and above all it implies in the highest animals a complex intelligence of which only a rudimentary prophecy exists in the lowest forms of life, possibly scarcely more than a mere sensation. We owe then to differentiation our faculties, which we prize. It is the result of differentiation that I am able to address you and present before you the thoughts which have been accumulated as the result of the studies of many years. It is a result of differentiation that you have such parts that you not only hear the actual sound of my voice, but interpret—at least I hope so—the meaning of my words and can understand the ideas which I am endeavoring to present to you. If you carry away something from these lectures, and recall it at some future time, that also will be a result of the differentiation of structure: for every one of you started as a minute germ, consisting of protoplasm with a nucleus, and entirely without any differentiation; and by a process so complex that the mystery of it escapes entirely all our powers of analysis, those parts which you have have been slowly and secretly fashioned. We have approached one of the fundamental problems of existence. When we talk of differentiation, we talk of the endowments which bring us into relation with the external world—into relations with our kind, and which make our internal life so complex, a complexity which in itself is a great problem. We touch here the fundamental mysteries of existence; we are hovering upon the outskirts of our human conceptions. We are not yet able to press beyond. But perhaps the time may come when the limit to which I can now bring you will be moved farther back, and some of the things which are at the present time utterly mysterious and incomprehensible to us will be comprehended and be explicable to you.

The increase of the protoplasm is then, as we have clearly seen from the pictures, the mark both of advancing organization and of advancing age. It is certainly somewhat paradoxical to assert that the increase of the protoplasm is a sign of old age, a sign of senescence, since protoplasm is the physical basis of life. It undoubtedly is such,

and we should hardly anticipate that its increase would have a deleterious effect. But such is, it seems to me, clearly the case. But it is not merely, of course, a question of the increase of protoplasm which we must bear in mind in estimating the cause and effect, but also the question of differentiation, in consequence of which protoplasm becomes something else and different from what it was before. This alteration, then, together with the increase of the protoplasm, is the change which in all parts of the body marks the passage from youth to old age.

It seems to me not going at all too far to say that the increase of protoplasm is a fundamental phenomenon. I wish to give you a more precise notion of this increase; and I am glad to be able to do so in consequence of a research carried on by Professor Eycleshymer in my laboratory and completed by him afterwards in his own laboratory at the University of St. Louis. He studied the development of the muscle fibers in the great salamander, known scientifically by the name of *Necturus*. These muscle fibers are somewhat cylindrical in shape. Their ends can be accurately determined so that the precise length of a fiber can be measured, and its diameter also. Hence the total volume of a fiber may be calculated. It is possible also to measure the nuclei and to count the number of nuclei in a fiber. Thus by measuring the diameter and length of the fiber, and then estimating the number and the diameters of the nuclei, we can calculate the proportions. As a matter of fact, the nuclei remain nearly constant in volume, not really quite so, but sufficiently constant to serve as a basis of measurement. Dr. Eycleshymer found that when a *Necturus* had a length of eight millimeters, it possessed, for each nucleus in its muscle fiber, 2,737 units of protoplasm, but when it was seventeen millimeters, it possessed for each nucleus 4,318 units per nucleus; at twenty-six millimeters, 8,473 units; and in the adult, which measures approximately 230 millimeters, it has 22,379 units per nucleus. In other words, as a salamander passes from the eight-millimeter condition, when the development of its muscle fibers is just fairly begun, up to the adult state, when the differentiation of the muscle fibers has been completed, it increases the proportion of protoplasmic substance and protoplasmic derivatives from 2,700 to 22,300 per nucleus. I give round numbers. The increase is approximately sevenfold. There is in the adult in the muscle fiber seven times as much protoplasmic substance in proportion to the nucleus as there was at the start of development when the muscle fiber could first be clearly recognized as such. This is an accurate measure and gives us a good idea of the general law of protoplasmic increase. It is the only instance, I yet know of, in which we have an accurate measure and can give quantitative values, though we do know that there is a more or less similar increase occurring in perhaps every tissue of the body.

While the increase of the protoplasm is going on, we find that there is an advance in the structure, in the differentiation. Now you may recall what I have mentioned earlier in this lecture, the further fundamental fact that the loss in the rate of growth is greatest in the young, least in the old, and that as we go back from old age towards youth, and then into the embryonic period, we find an ever-increasing power of growth, but that it is during the embryonic period that the loss of the power of growth is greatest. It is to the embryonic period, therefore, that I have turned in order to ascertain whether the rate of differentiation shows a similar relation in the development of the organism.

We have a large series of microscopic preparations of rabbit embryos in the embryological laboratory of the Harvard Medical School. Utilizing these, I found that at seven or eight days of development there is scarcely a trace of differentiation. The cells are in the condition of those which I showed to you earlier in the lecture upon the screen. At sixteen and a half days, a stage of development of which I have some good preparations, I found that a great deal had been accomplished. At seven days there was no brain, there was no spinal cord, nothing that could possibly be called skin or muscle, or intestine or heart. None of those things were yet produced. But at sixteen and one half—in other words, after a very brief period indeed—only nine days of the whole life of the animal—there have arisen from this inchoate beginning all the principal organs of the body. The brain is there, divided up into its principal fundamental parts; the spinal cord has its nerves in connection with the various parts of the body; there is a trace of the skeletal element; the stomach, the liver, the pancreas, the intestines, are all present and well defined; the heart is a large and beating organ, amply supplied with blood, connected with vessels, which carry out and bring back the blood and are all far along in their development. Equally instructive is the microscopic examination, for we can see that the cells themselves have been changed. Not only have the great organs been mapped out in this brief period, but the cells which belong to them have for each organ acquired a characteristic quality. In the brain there are nerve cells with their long processes to carry the impulse in; the single process (axon) to carry it out. The glands in the stomach have the cells which are to build them already there. The muscles which are to move the stomach are beginning to appear as cells of a special form. Nerve fibers extend down into the gastric region and to the various distant organs of the body. Muscle fibers can be recognized along the back and in the limbs, and so in every part of the body we can detect cells already far advanced in their development. It is not certainly too much to say that in the brief period of these nine days fully as much differentiation has been accomplished as is accomplished during the entire remainder of the life of the animal. We do not, at present at least, possess any method of measuring dif-

differentiation, which enables us to state it numerically, but no one who is familiar with these matters and observes the structure, as I have myself observed it, would hesitate for a moment, it seems to me, to decide that my assertion is perfectly within the bounds of truth, that within a period of nine days, half of the entire differentiation which is to occur in the whole life of the rabbit has been completed. We must from this conclude that the rate of differentiation is very rapid at first and afterwards declines, and as we compare the different stages of development we can see readily that this is the case. The progress in the additional development in the rabbit from sixteen and one half days up to the time of its birth is far greater than the progress which occurs after birth. We find, moreover, in the study of these embryonic conditions, some instructive things, for in certain parts of the body the process of differentiation hurries along, and as the cells are differentiated their power of growth, to a large extent, is stopped. On the other hand, there are various provisions in the developing animal for keeping back certain cells, allowing them to remain in the young state. Such cells may afterward differentiate.

From all that has been said it seems to me legitimate to conclude that there is an intimate correlation between the rate of differentiation and the rate of growth. I am inclined to go the one step farther, and bring them into the relation of cause and effect; and I present to you as the main general conclusion of this first part of our series of lectures, the conception that *the growth and differentiation of the protoplasm are the cause of the loss of the power of growth*. Now if cells become old as their protoplasm increases and becomes differentiated, we should expect to find that there would be a provision for the production of young cells. It is rather mortifying to reflect that the simple conception which I have now to express to you, although it lay close at hand, failed to combine itself in my mind for many years with the conception of the process of senescence as I have just described it to you. It is somewhat, it seems to me, like two acquaintances of mine who lived long side by side, seeing one another frequently until they were fairly past the period of youth, when their attachment became very close and by a sacrament they were permanently joined together. So in the minds of men often two ideas lie side by side which ought to be married to one another, and there is no one ready, so dull is the owner of the mind, to pronounce the sacramental words which shall join them, and the rite long remains unperformed, and when at last such neighbor ideas, which naturally should be united in close companionship, are brought together and made, as it were, into one, we are astonished that the inevitableness of the union had not obtained our notice before, it is so very obvious. And so in regard to the conception of what constitutes the restoration of the young state, I have only this excuse to offer, which I have indicated to you, that even the

natural thought fails to occur to us. We are very dull even if we are scientific.

The pictures now before you represent certain early stages in the progress of development of a mammal by the name of *Tarsius*, a creature related to the lemurs. The various figures illustrate the multi-

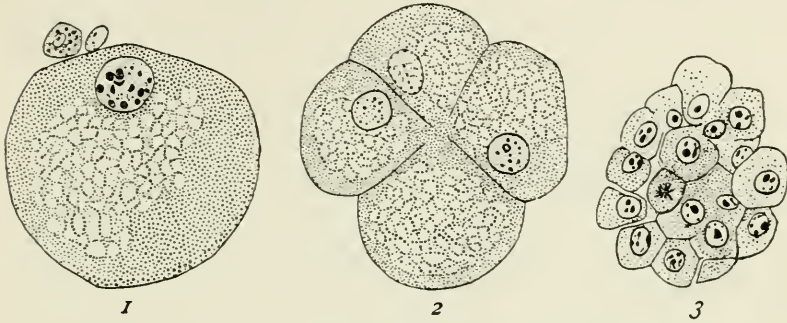


FIG. 49. *Tarsius spectabile*. SECTIONS OF THREE OVA IN VERY EARLY STAGES. 1, before cleavage; 2, cleavage into four cells; 3, multicellular stage.

plication of the cells. That which I wish to call your attention to can be well demonstrated by the comparison of the first figure, in which there is a single nucleus, with the figure at this point having a number of nuclei. Both figures represent the very earliest stages of development and show the full size of the whole germ, which is about the same in the two stages. The total amount of living material has not changed essentially, but evidently there has occurred a marked increase of the nuclear substance. The nuclei have in the right-hand figure multiplied in number and their combined volume is much greater than the total volume of the single nucleus in the left-hand figure.

We can get a further notion of the nuclear increase by studying the very early development of a salamander. Here upon the screen is the egg of a salamander. It represents really but a single cell. It then divides into two cells; each of those cells has a nucleus which we can not see because these pictures are taken from the living egg, and the living egg is not transparent. Here it is dividing into four, here the upper portion of the four cells has been split off, and we have seven cells showing in the figure, and an eighth on the back. Here the number of cells has increased very much, and as you view these figures you will notice that they look very much indeed like oranges divided into segments. It seems, in fact, as if this egg, which was spherical in form, were being divided up into a certain number of segments. The process was first observed in the eggs of some of the amphibia, frogs, toads and salamanders, and it was therefore called segmentation, because it was not known at that time what the process really meant. We have then before us an ovum and a series of stages of the segmentation of the ovum, and the result of that segmentation is to produce an

ever-increasing number of cells which, in the last of the figures upon the screen, have become so numerous that we are no longer able to readily count them. Every one of these cells has its own nucleus. When the process of segmentation is complete and reaches its final limit, we then see, if we examine that stage of development, cells of the young type, such as I have described to you, in which there is a nucleus with a small amount of protoplasm about each nucleus. It seems to me, therefore—and this is a new interpretation which I present

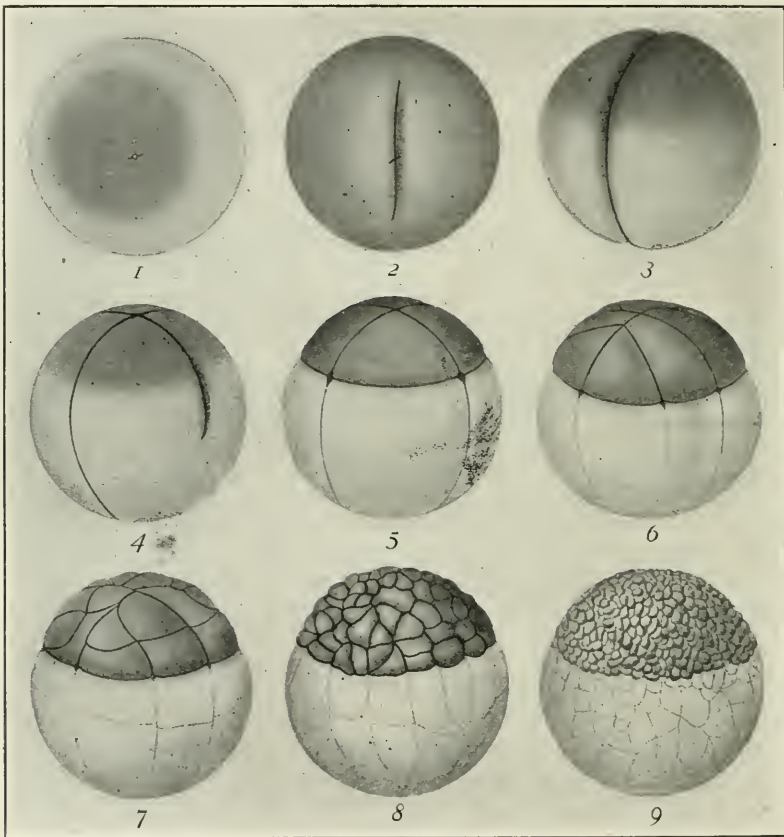


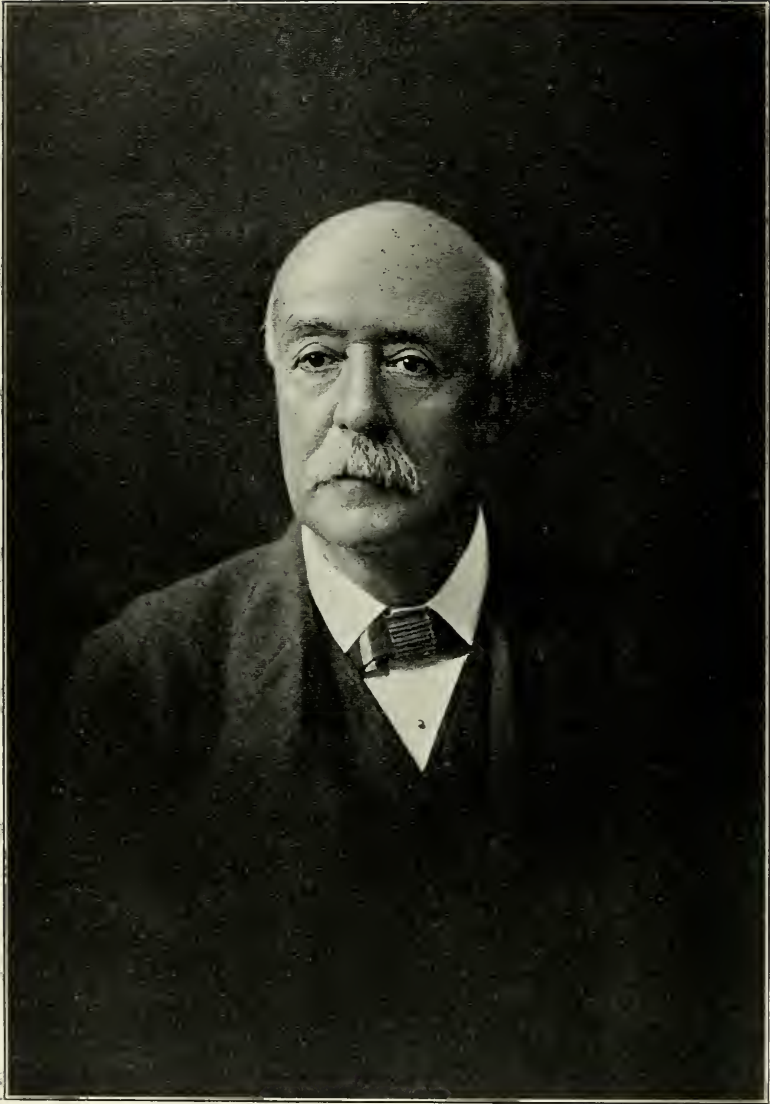
FIG. 50. *Amblystomum punctatum*. PROGRESSIVE SEGMENTATION OF THE OVUM. 1, unsegmented ovum; 9, advanced segmentation.

to you—that the process of segmentation of the ovum, with which the development of all the animals of the higher type invariably begins, is really the process of producing young cells. It is the process of rejuvenation. There is not any considerable growth of the living protoplasmic material of these eggs, and at the final stage the total volume of the egg is scarcely bigger than before; and such increased volume as has occurred has been due to the absorption of some of the surrounding water. In many animals not even this increase by the absorption

of water takes place. During the segmentation of the ovum the condition of things has been reversed so far as the proportions of nucleus and protoplasm are concerned. We have nucleus produced, so to speak, to excess. The nuclear substance is increased during this first phase of development.

Naturally, as we embryologists looked upon these things in earlier days and thought of the progress of development, we conceived of the earlier stage as younger, and of the ovum as being the youngest stage of all, a conception which in terms of time is obviously correct, but as regards the nature of the development, it seems to me clearly, is not correct. The ovum is a cell derived from the parent body, fertilized by the male element, and presenting the old state to us, the state in which there is an excessive amount of protoplasm in proportion to the nucleus; and in order to get anything which is young, a process of rejuvenation is necessary, and that rejuvenation is the first thing to be done in development. The nuclei multiply; they multiply at the expense of the protoplasm. They take food from the material which is stored up in the ovum, nourish themselves by it, grow and multiply until they become the dominant part in the structure. Then begins the other change; the protoplasm slowly proceeds to grow, and as it grows, differentiation follows, and so the cycle is completed. Whether other naturalists will be inclined to accept this conception that the process of the segmentation of the ovum is that which we must call rejuvenation or not, I can not say, for the matter has as yet been very little discussed, but you will see that it hangs as a theory well together. We have first an explanation of the process of the production of the young material, and out of that young material the fashioning of the embryo. The cycle of life has two phases, an early brief one, during which the young material is produced, then the later and prolonged one, in which the process of differentiation goes on, and that which was young, through a prolonged senescence, becomes old. I believe these are the alternating phases of life, and that as we define senescence as an increase and differentiation of the protoplasm, so we must define rejuvenation as an increase of the nuclear material. The alternation of phases is due to the alternation in the proportions of nucleus and protoplasm.

In the next lecture I shall be able to convince you, I hope, that this conception of the relation of the power of growth to the proportion of nucleus and protoplasm enables us to understand various problems of development, certain possibilities of regeneration and reconstruction of lost parts, and that it also leads us naturally forward to the consideration of the problem of death as it is now viewed by biologists, so that our next lecture will be upon the subject of regeneration and death, the natural topics to follow after to-night's discussion.



MR. ALEXANDER AGASSIZ.
President of the Seventh International Zoological Congress.

THE PROGRESS OF SCIENCE

THE INTERNATIONAL ZOOLOGICAL CONGRESS

THE Seventh International Zoological Congress, held at Boston on August 19-24, was probably a greater success than its promoters had ventured to hope. Although it may have seemed inappropriate to hold it anywhere but in, or close to, Agassiz's famous museum at Cambridge, all disappointment on this score was quickly forgotten upon reaching the magnificent new buildings of the Harvard Medical School. Rarely had zoologists been so splendidly housed; and never, perhaps, had they received more open-handed hospitality from the people among whom they had chosen to meet. The attendance at the congress was very large, including distinguished workers from Japan, Russia, Austria, etc., with large delegations from Germany, France and England. No single man can sum up the achievements represented by the assembly, but counting work instead of heads, it is possible that as much as one fourth of the total zoological strength of the world was represented. The papers and addresses, as at all such gatherings, were of all degrees of interest and importance; but it is certainly true that many noteworthy contributions were offered. Perhaps the greatest enthusiasm was aroused by Bateson's address on problems connected with heredity. The whole subject of genetics, as Bateson calls it, was very much to the front, and anything in reference to it was eagerly received. Tower, of Chicago, the author of the remarkable researches on the potato-beetle and its allies, was present; and Shull's account of his experiments with the "elementary species" of shepherd's purse was welcomed, though actually

botanical. It is an interesting sign of the times that a paper dealing exclusively with plants should be considered appropriate at a zoological congress; an indication that biology is again coming to be studied in a broad way, and that one can not afford to ignore either animals or plants, when dealing primarily with the one or the other.

At the general meetings, held at Jordan Hall, it was a keen pleasure to see and hear such standard bearers of the science as Hertwig, Murray and Brooks, not to speak of Alexander Agassiz, the president of the congress. At the last general meeting the report of the committee on nomenclature was unanimously adopted, and thus some matters of importance, which had long been in dispute, were at length settled, so far as they can be by such means.

Several excursions were arranged for the members of the congress. One to the Arnold Arboretum gave the foreigners an opportunity of seeing a fine series of living American trees; while the geneticologists, if one may so call them, were glad to be conducted by Professor Sargent through his plantation containing species of thorns. Another party was conducted to the place where extensive experiments are being made in rearing the parasites of the gypsy moth, and all who saw this work came back with enthusiastic accounts of it. On another day the congress was entertained at Wellesley College; while on Saturday a visit was made to Harvard University, where President Eliot and Mr. Agassiz made brief speeches explaining the history and nature of Harvard University in general and the Museum of Comparative Zoology in particular.

At the termination of the Boston



MEMBERS OF THE INTERNATIONAL ZOOLOGICAL CONGRESS



AT THE HARVARD MEDICAL SCHOOL.

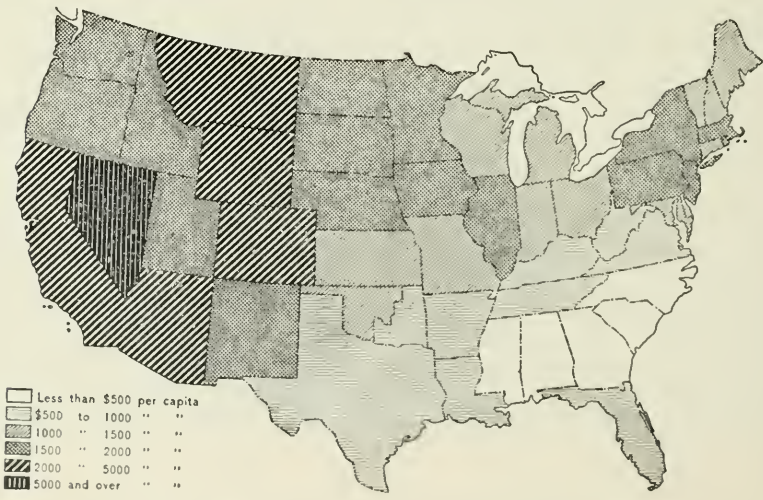
week the congress went to Woods Holl, where they were shown all that the laboratories held. A pleasing feature of this visit was the reading of a letter from Dr. Dohrn, of the Naples Zoological Station, regretting his inability to be present, and the sending to him of a warm message of regard, signed by all in attendance. In the afternoon of Sunday the members embarked on the *Fishhawk*, on their way to New York, a sample dredging being made so that all might see the method employed by the Bureau of Fisheries in exploring the local waters.

The excursion was continued in New York, Philadelphia and Washington, the members being elaborately entertained in each city, with special reference to the scientific and zoological interests. Thus in New York a day each was devoted to Columbia University, the American Museum of Natural History, the Station for Experimental Evolution of the Carnegie Institution at Cold Spring Harbor, New York, the Zoological Park and a trip up the Hudson to Garrison as guests of Professor Osborn. On Saturday there were trips to Yale and Princeton. On Monday and Tuesday in Philadelphia

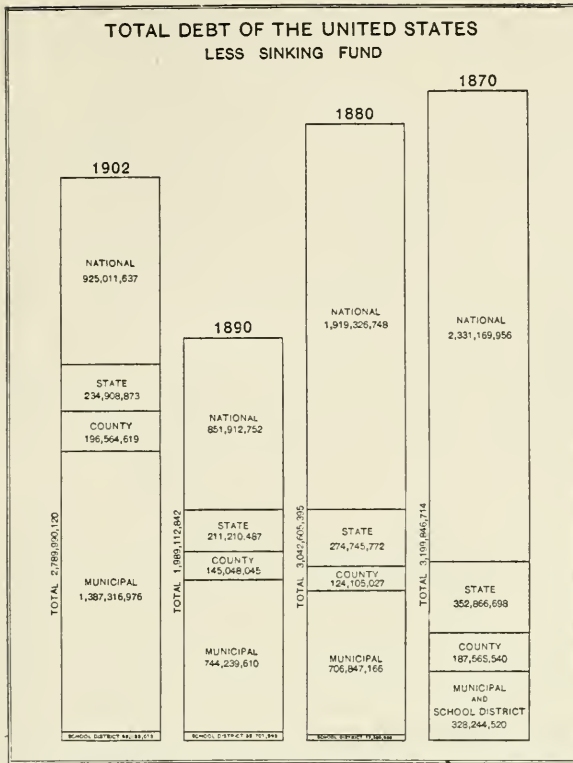
the members visited the Academy of Natural Sciences, the Zoological Garden, the American Philosophical Society and the University of Pennsylvania. At Washington the visitors were welcomed by Secretary Wilson and shown under the most favorable auspices the vast work being accomplished for science by the national government. A trip to Niagara Falls and the University of Toronto completed the excursion, which had been remarkably well arranged and with which the foreign delegates expressed themselves as more than pleased.

THE WEALTH OF THE UNITED STATES

The census office has issued a report of more than 1,200 quarto pages containing a vast amount of information in regard to the wealth, debt and taxation of the country in 1904. The total wealth is placed at about 107 billion dollars, as compared with 88 billion in 1900, 65 billion in 1890 and 43 billion in 1880. The per capita wealth is now \$1,318, and the annual increase not far from \$40 per year. While the per capita wealth of Great Britain, France and Australia is



PER CAPITA WEALTH FOR EACH STATE AND TERRITORY, 1904.



slightly larger, the total wealth of the United States surpasses by far that of any other country. The per capita distribution, as shown on the map, will surprise some readers. It is over \$5,000 in Nevada, and over \$2,500 in California and Montana, whereas it is under \$2,000 in New York, Pennsylvania and Massachusetts. It is greater in Iowa than in Pennsylvania or Illinois. The form of wealth is in round numbers distributed as follows: Real property and improvements, 63 billion dollars; live-stock and farm implements, 3 billion dollars; manufacturing machinery, 3 billion; gold and silver bullion, 2 billion; railways, 11 billion; street-railways, etc., 5 billion; manufactured products, etc., 18 billion.

The total national, state and municipal debt of the country in 1902 was about two billion, seven hundred and ninety million dollars, or \$35.50 per

capita. This is an increase of about 800 million dollars since 1890, but a decrease as compared with 1880. The accompanying chart shows the distribution of this debt, the most striking fact being the steady decrease in the debt of the national government and the increase in municipal debts. This is of course a gratifying change, the national debt being due to the cost of war, and municipal debt in the main to improvements of lasting value. The per capita national debt has decreased from \$60.46 in 1870 to \$11.77 in 1902. As the rate of interest has very greatly decreased, the burden of the national debt on each individual is now comparatively slight. It would, however, seem to be only the prudence that is expected from each citizen for the whole nation to pay its debt without undue delay. It is a question whether it would not be wiser for municipalities

to invest their savings in improvements rather than to contract debts, but this is an open question, as it is reasonable to expect future years, and even future generations, to pay for advantages that may be bequeathed to them. The report contains a very elaborate discussion of the taxation and revenue systems of the United States and of the several states. In 1902, the total expenditures of the national government were about 617 million dollars; of the states and territories, about 85 million; of the counties, 197 million; of the cities 551 million, and of other minor civil divisions 222 million. The receipts from revenues almost exactly balance the expenditures.

SCIENTIFIC ITEMS

We record with regret the death of Dr. William Thomson, an eminent ophthalmologist of Philadelphia, and of Dr. Gaylord P. Clark, dean of the college of Medicine and professor of physiology at Syracuse University.

PROFESSOR LUDWIG VON GRAFF will be president of the eighth Zoological Congress, which is to be held at Graz three years hence.—Professor J. J. Stevenson, of New York University, and Professor W. M. Davis, of Harvard University, were delegates from the Geological Society of America to the centennial celebration of the foundation of the Geological Society of London, which took place at the end of September.

DR. E. RAY LANKESTER will retire from the directorship of the Natural History Museum, London, in October. It is understood that the inadequate pension originally proposed by the trustees has been about doubled. The trustees have decided not to appoint a new director, though it is possible that this plan may be changed.—At the Meudon Experiment Station, which is affiliated with the Collège de France, M. Daniel Berthelot has been appointed director of the laboratory for plant physics, and M. Muntz, director of the laboratory for plant chemistry.—By an act of the last legislature, the professor of geology at the State University of Colorado became also, by virtue of his office, the state geologist. \$5,000 is appropriated annually for this service.

YALE UNIVERSITY has received a bequest calling to mind that of Smithsonian for the establishment of the Smithsonian Institution. Archibald Henry Blount, an Englishman, who is not known to have been in America or to have had any connection with Yale University, has made that institution his residuary legatee, to which it will profit to the extent of about \$400,000. Yale University has also received \$150,000 for a lecture hall for the Sheffield Scientific School. This is a gift of Mrs. James B. Oliver, in memory of her son, a former student of the school, who was recently killed in an automobile accident.

THE POPULAR SCIENCE MONTHLY

NOVEMBER, 1907

THE SCOPE AND IMPORTANCE TO THE STATE OF THE SCIENCE OF NATIONAL EUGENICS¹

BY PROFESSOR KARL PEARSON, F.R.S.,
UNIVERSITY OF LONDON

IT needs more than a little boldness to suggest within the walls of one of our ancient universities that there is still another new science which calls for support and sympathy; nay, which in the near future will demand its endowments, its special laboratory, its technical library, its enthusiastic investigators and its proper share in the curriculum of academic studies.

The prestige of an ancient university does not wholly depend on the extent and novelty of the fields it cultivates, nor even on the external reputation of its doctors and masters. I remember my Savigny well enough to know that historically a university does not express the universality of the learning taught within its walls, but that the word emphasizes the corporate character of its masters and scholars. I also understand—with the experience of four universities behind me—not only the social, but the educational value of the traditional *universitas* of the middle ages; that common life of teacher and scholar which we now find preserved in broad outline, if in detail obscured, at two English universities alone.

As your guest to-day, even if I had the necessary knowledge, it would be ill-fitting to praise or to criticize modern Oxford. My intellectual debt to Oxford is too great to make me an unbiased judge; looking back on the stadia of intellectual growth from the days of the Oxford schoolmaster who taught me scientific method and a love of folk-lore in failing to teach me Greek grammar, the sign-posts are marked with Oxford names, whose moment to me must be a small part of what it formed to the mental life here. I note those: of Mark

¹ Fourteenth Robert Boyle lecture delivered before the Oxford University Junior Scientific Club on May 17, 1907.

Pattison, from whom I learned that the method of science is one with the method of true scholarship; of Henry Nettleship, whose width of view in academic matters aided those of us who were struggling against prerogative and prejudice in London; of York Powell, who taught me that a study of history is incomplete if it pass by the great biological factors which make for the rise and fall of nations; of Raphael Weldon, whose life culminated in Oxford, and whose activity will, I trust, continue to bear fruit here—of Weldon who taught us that biology is ripe for receiving aid from the exact sciences; who, breaking down yet another barrier, emphasized the unity of logical method throughout the whole field of knowledge.

The calm, critical judgment of these men, their scorn, one and all, for the rhetorical, the superficial, the *idola* of the market-place, have built up my Gentile conception of Oxford and given me a not unwholesome fear of an Oxford audience. Their keen power of sympathy, however, their very intense, if much repressed, national spirit—amounting to the truest form of patriotism—would, I believe and trust, have been not wholly withdrawn from me to-day in my endeavor to put before you the claims of this new science of mankind.

I do not demand your attention for this new field of inquiry because a university is expected to embrace all sciences. On the contrary, I do it partly because I think the success of a university, as of an individual, depends largely on specialization in study. Now there is one form of technical education, which, although Oxford is too modest to give it a name, has yet been largely claimed for this university. I refer to the education of statesmen and administrators. There is need, I venture to hold, of a more conscious recognition of the existence of a school of statecraft, and that recognition must involve a fuller study of what can make and what can mar national life and racial character. We are told by a poet, who, understanding the spirit of his age, carefully balanced himself on the fence which separates the field of true insight from that of conterminous platitude, that "the proper study of mankind is man." But he has not helped us to see wherein this proper study of man consists. In all our universities there are branches of study which deal more or less directly with man. We have philosophy with its discussions of man's mental processes, ethics with the consideration of man's affections, passions and conduct; Fichte, Hegel and other ethical philosophers have given us, here and there, luminous ideas, flash-lights on society and state. But has philosophy, as such, taught us a single law by aid of which we can understand how a nation becomes physically or mentally more vigorous? Has it taught our statesmen to make their folk fitter for its task on the world-stage, or helped a race to meet a crisis in its history? We have had other branches of the science of man, measuring him, classifying him by his hair, by his skin or by his skull. Yet anthropometry and craniometry,

while piling up facts and figures, have done little to enable us to see wherein human fitness for its functions really consists. Their professors disagree, much as do those of another branch of the study of man—political economy. What weight have philosophy, anthropology or political economy at present in the field of statesmanship? Would the man who, rising in the House of Commons to-day, appealed to the laws of economic science, be even sure of a hearing? And if we turn to the study of history, surely more potent than these other branches in the aid it provides for the administrator, is not its lesson rather that of example and analogy than of true explanation and measurement of the causes of national evolution?

If the German people dominates to-day the French; if Japan rises like a mushroom—with the stability and the strength of the oak; if Spain and Holland disappear from the fore rank of nations, can we throw light even for an instant on these momentous facts of history by such studies of mankind as are summed up in philosophy, anthropology or political economy? I fear not. As instruments of education, as means of illustrating logical method, or of developing powers of healthy inquisitiveness and effective expression, they may be of value, in part indeed of unrivaled value. But as they stand at present they do not, alone or combined, form a technical education in statecraft.

And here I would like to make a fundamental distinction between what I understand by a technical education and a professional instruction. I do not believe that the university ought to busy itself in the least with the latter. It is taught most effectively in the barrister's chambers, in the architect's office, in the engineering workshop, in the government department, or in the hospital ward. The tendency nowadays to replace apprenticeship by professional instruction in college or university is a fatal one. The academic purpose should be concentrated on the development of the mind as an instrument of thought. It may do this by aid of philosophy, or by aid of language, or of science; but it can not do it by any form of purely professional instruction. By technical education I mean something very different from an instruction in the facts, formulæ and usages of a profession. It consists, I hold, not in learning an art, but in developing the mind by studying that branch of science which must lie at the basis of each profession. The theory of elasticity is as potent an instrument for mental discipline if we illustrate it on bridge-structure, as if we confined our attention to metal spels and snips of pianoforte wire in the physical laboratory. The science of medicine—think for a moment even of such points as immunity, incubation and crisis—affords material for reasoned observation and leads to a mental alertness, which may be equaled but can not be excelled in any other branch of biological inquiry. The true test of all technical education lies in whether we can answer in the affirmative the question: Does it provide adequate mental training for the

man who has no intention of professional pursuits? If we can, then, and then only, may we assert that it is a fit subject for academic study.

By a superficial knowledge of many things, we break all continuity in education; we may reach a "top-dressing," but the subsoil has never been turned and cultivated. From this standpoint, academic education will, I feel certain, grow more and more technical education; the man who has exercised his mind in thoroughly examining one small field of knowledge, who has seen its solved and unsolved problems, and who has tried his own powers in even some little bit of pioneer work, has received a training which will stand him in good stead, whatever he may afterwards turn his mind to in life. I can conceive a great university for the training of mind, in which the whole teaching force should be devoted to the manufacture of problems, calculated to exercise and develop the youthful mind, without any regard to their bearing on real knowledge. Such was very nearly the system of the Cambridge mathematical school of a generation ago. It produced splendid lawyers, subtle theologians and a few ardent students of science. But the labor expended in the manufacture of problems, the sole purpose of which was to provide material for mental gymnastics, might have achieved European reputation for the manufacturers had it been devoted to the pressing problems of technical science. It is because every university has a duty in the creation of new knowledge, as well as a duty in education, that it seems desirable that our mental training should take as its problems those which are actually demanding solution in practical life.

If we are to have a school of statecraft, I venture to suggest that a special technical education shall be developed for it. We must not be content with the mental gymnastics which can be provided by philosophy or political history. We must add that study of the biological factors which York Powell saw was so needful to historical investigation. We must approach with the detached mind and calm criticism of Mark Pattison those problems as to the rate of change of races, a knowledge of which Raphael Weldon has told us is "the only legitimate basis for speculations as to their past history and future fate."

If we attempt to define the scope of statecraft we enter no doubt the field of controversy, but may we not extend the condition which so fitly expresses the primary need of the individual—the healthy mind in healthy body—to the swarm of individuals with which the statesman has to deal? Taking the word "sanity" in its broadest sense of health and soundness, the primary purpose of statecraft is to insure that the nation as a whole shall possess sanity; it must be sound in body and sound in mind. This is the bedrock on which alone a great nation can be built up; by aid of this sanity alone an empire once founded can be preserved. There are secondary important conditions—too often regarded as primary—which are undoubted parts of statecraft. The nation must have the instruments and the training needful to protect

itself and its enterprises; it must hold the sources of raw material and the trade routes requisite to develop the wealth upon which its population depends; it must have the education necessary to make its craftsmen, its traders, its inventors, its men of science, its diplomatists and its statesmen the equals at least of those of its rivals on the world-stage. Nay, perhaps as important as all these, it must have traditions and ideals so strong that the prejudices of individuals and the prerogatives of classes will fall before urgent national needs; it requires teachers, be they pressmen, poets or politicians, who grasp the wants of the nation as a whole; who, independent of class and party, can remind the people at the fitting moment of their traditions and their special function amid nations.

Yet if we come to analyze these secondary conditions, we shall find in each case that their realization depends on the fulfilment of our primary condition. Without high average soundness of body and soundness of mind, a nation can neither be built up nor an empire preserved. Permanence and dominance in the world passes to and from nations even with their rise and fall in mental and bodily fitness. No success will attend our attempts to understand past history, to cast light on present racial changes, or to predict future development, if we leave out of account the biological factors. Statistics as to the prevalence of disease in the army of a defeated nation may tell us more than any dissertation on the genius of the commanders and the cleverness of the statesmen of its victorious foe. Lost provinces and a generation of hectoring may follow to the conquered nation whose leaders have forgotten the primary essential of national soundness in body and mind.

Francis Galton, in establishing a laboratory for the study of national eugenics in the University of London, has defined this new science as "the study of agencies under social control that may improve or impair the racial qualities of future generations, either physically or mentally." The word *eugenic* here has the double sense of the English *well-bred*, goodness of nature and goodness of nurture. Our science does not propose to confine its attention to problems of inheritance only, but to deal also with problems of environment and of nurture. It may be said that much social labor has already been spent on investigating the condition of the people; there have been royal commissions, parliamentary and departmental committees, and much independent effort on the part of philanthropists, medical men and social reformers. I would admit all this, and would try to appraise it at its true value. Some of it has provided useful material for eugenic study; much of it is the product of wholly irresponsible witnesses with comments by commissioners equally untrained in dealing with statistical problems. Witnesses, commissioners, philanthropists, social reformers, as a rule, and medical men only too frequently sadly need that technical education, that power of reasoning about statistical

data, which I think will become general when eugenics has been made a subject of academic study, and minds specially trained to this branch of scientific inquiry are placed at the disposal of our statesmen. I do not, of course, say that there was no eugenic research before Francis Galton invented the word and named the new science. But I believe the day not distant when we shall recognize that he seized the psychological moment to assert its claim to academic consideration; and that in the time to come the nation will be more than grateful to the man who said that the university is the true field for the study of those agencies which may improve or impair our racial qualities. To become a true science, you must remove our study from the strife of parties, from the conflict of creeds, from false notions of charity, or the unbalanced impulses of sentiment. You must treat it with the observational caution and critical spirit that you give to other branches of biology. And when you have discovered its principles and deduced its laws, then, and then only, you can question how far they are consonant with current moral ideas or with prevailing human sentiment. I myself look forward to a future when a wholly new view as to patriotism will be accepted; when the individual will recognize more fully and more clearly the conflict between individual interests and national duties. I foresee a time when the welfare of the nation will form a more conspicuous factor in conduct; when conscious race-culture will cope with the ills which arise when we suspend the full purifying force of natural selection; and when charity will not be haphazard—the request for it being either a social right, or the granting of it an anti-social wrong. But if we are to build up a strong nation, sound in mind and body, we shall have to work in the future with trained insight: I feel convinced that real enlightenment will only follow a scientific treatment of the biological factors in race development.

There is an element of danger in the study of eugenics, which I would not have you overlook. If the attention be fixed on the factors which make for deterioration; if we spend our days over statistics of the insane, the mentally defective, the criminal, the tuberculous, the blind, the deaf and the diseased, the inevitableness of it all is apt to reduce us to the lowest depths of depression. But this is only one side of the picture; the inevitableness is just as marked when we come to deal with health and strength, with ability and intelligence. If the iniquity of the fathers be visited upon the children to the third and fourth generation—assuredly so is their virtue. If this needs emphasis, study the two pedigrees I put before you. In Fig. 1 we have the pedigree of a family in which eccentricity, insanity and phthisis have recurred generation by generation—associated occasionally with great ability. The general “want of mental balance” is the mark of the stock. In Fig. 2 we have the pedigree of a family in which extreme

ability not correlated with such want of mental balance has descended through five generations.

Yet apart from this, to the true man of science, nothing is impure or repulsive. His mission is to study all phases of life; and in the case before us to determine their relation to national fitness and racial degeneracy. I can not put it better than in the words of Francis Bacon:

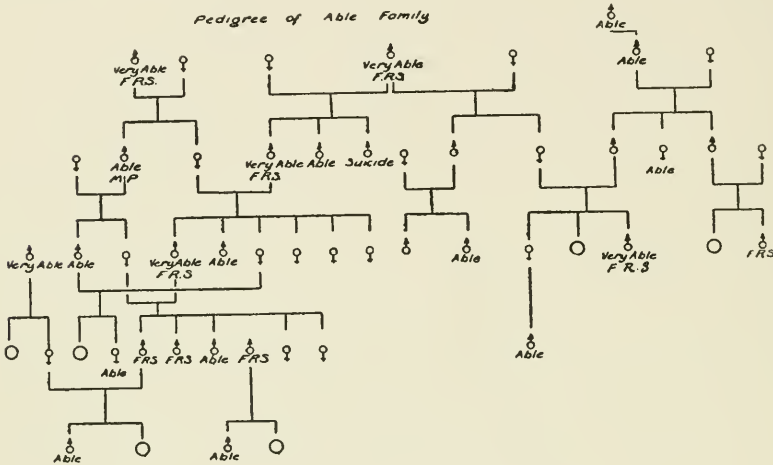


FIG. 2.

But for unpolite or even sordid particulars which, as Pliny observes, require an apology for being mentioned, even these ought to be received into natural history, no less than the most rich and delicate; for, natural history is not defiled by them any more than the sun, by shining alike on the palace and the privy; and we do not endeavor to build a capitol or erect a pyramid to the glory of mankind, but to found a temple in imitation of the world, and consecrate it to the human understanding, so that we must frame our model accordingly; for whatever is worthy of existence is worthy of our knowledge; but ignoble things exist as well as the noble.

Those who have not the courage, or it may be the strength to face life as it is, must avoid science; or at least the portion of it termed national eugenics. Those who fear to know humanity in its degradation, as well as in its nobler phases, will scarce reach the standpoint of knowledge from which they can effectively help the progress of our race. They will be ignorant of the essential factors which alone can determine whether a nation shall be sound in mind and body. Disease and health, vigor and impotence, intelligence and stupidity, sanity and insanity, conscientiousness and irresponsibility, clean living and license—all things which make for strength and weakness of character—must be studied, not by verbal argument, but be dissected under the statistical microscope, if we are to realize why nations rise and fall, if we are to know whether our own folk is progressing or regressing. Only by such examination can we understand the disease; only by such means can we suggest a valid cure where we find there is that in any com-

munity which is making for degeneracy. The study of eugenics centers round the actuarial treatment of human society in all its phases, healthy and morbid.

In every branch of science there exist, I believe, three chief stages of development. These stages are not always completely differentiated, and forms of the earlier stages may usefully survive into the later periods.

The first stage is the *ideological*. Men have formed ideas about phenomena on the basis of very limited experience. They spend their time and energy in discussing these ideas without much reference to the phenomena themselves. This discussion of ideas—this wrangling over definitions—is not idle. It not only led in medieval times to a philosophy which gave a by no means contemptible educational training; but in some of the most developed forms of science, as in the foundations of our most advanced pure mathematics, ideology can again do work of the greatest service. It corresponds to the pre-Baconian state of most sciences.

The second stage is the *observational*. It is a reaction against the purely introspective attempt at a natural philosophy. It consists in observing phenomena critically, and recording and describing their sequences. It is a fundamental stage towards any really scientific theory of nature. It will always remain a large factor in scientific work. But while it needs the mind of special width and creative power to invent a reasonable theory, and demonstrate it by the right type of observation, it is possible for the average man to observe carefully and to go on observing through a long lifetime. The result is the accumulation for decades and decades of observations made with little idea of testing a definite theory of organic or inorganic nature. These observations form a large proportion of scientific literature; and, I fear, are not always of service when the creative scientist desires to test his theories. The time spent in hunting up data, which may after all fail to give the special small detail requisite, would often have sufficed to produce more adequate observations made *ad hoc*. Hence I think there will be, if there be not already, a reaction against purely observational or descriptive science.

The third stage in all science is the *metrical*. We proceed from observation to measurement, to accurate numerical expression of the sequences involved. It has been more than once asserted that by quantitative analysis you can not obtain more than lies in the data from which you start. The statement is either merely platitude; or else, if more than idle, it is false. The object of analysis is *not* to obtain more from data than exists therein; but to find out what actually does exist therein; and that is usually far from obvious to untrained inspection. The actual positions of the moon can be observed and recorded day by day. Such are the data. Shall we assert that lunar theory as it

exists to-day—the product of nearly two and a half centuries of work by some of the finest mathematical intellects—contains no more than the data from which they started? I think we may leave such an attitude to those who do not grasp that the highest aim of science is not the presentation of facts, but the regulating of a world of conceptions, by aid of which we can mentally describe those facts. From the data themselves we have to determine whether this “statuting of mind” is legitimate within the limits of our observations. “Analysis can not get more out of the data than is already in them,” cries the biologist. On the contrary, having added to the data *mind*, the combination provides a great deal that had no previous existence. Even Huxley could write:

Mathematics may be compared to a mill of exquisite workmanship, which grinds your stuff to any degree of fineness, but nevertheless what you get out depends on what you put in; and as the grandest mill in the world will not extract wheat-flour from peascods, so pages of formulæ will not get a definite result out of loose data.

On the contrary, I assert that our modern mathematical methods reach a perfectly definite result when applied to such data; they measure the deviation, the differentiation of pease-meal from wheat-flour; that is to say, they determine quantitatively the exact degree of looseness in the data themselves. Is it fear of discovering the exact degree of looseness in their own data, which leads some votaries of descriptive science to belittle metrical investigations?

Nay, I do not hesitate to assert that any branch of science, until it reaches its third or metrical stage of development, is incomplete and fails to provide the highest mental training possible. There are few departments of scientific investigation which provide so thoroughly for discipline in all the three branches of science, the ideological, the observational, and the metrical, as biology; this is particularly true of its applications to man. What better training in ideology than a study of the theory of the state from Plato, through Aristotle and Hobbes till we reach, in Comte, the view that the science of society is impossible without biology? What fitter training in observation than the biologist provides, when he teaches us experimentally the facts of inheritance and the influences of environment? What more precise exercise for the mind than the actuarial appreciation of these biological factors “as agencies which improve or impair the racial qualities of future generations”?

Here, I firmly believe, is in broad outline the scheme necessary to form a school of statecraft. The mind must be led through each of the ascending stages of science—till it is able to measure accurately and to describe in fitting words those fundamental biological factors on which the progression and the debasement of human societies alike depend.

But you may ask me if I am not painting a science of the future;

if I am not merely repeating the vague words of the old sociologists, from Comte to Herbert Spencer? Where is the material, what are the methods, how definite are the deductions of this new science of eugenics?

First then: where is the material?

I reply that every large school and university in this country can provide physical and psychical material for the student of eugenics if he will set to work and observe. Every medical officer in asylum and hospital is in charge of a great eugenics laboratory if he would only realize it. And many indeed are realizing it. Quite recently between 300 and 400 pedigrees of tuberculous stock; 400 family histories of insanity; 400 descriptions of parentage and home environment of mentally defective children, with as many of normal children from one district, and upwards of 1,000 from a second district, have reached the Eugenics Laboratory in London. If this seems to lay all stress on the abnormal and defective side, I may add that the laboratory possesses records of nearly 400 noteworthy families—a part of which have been published—and that I have reached now a series of nearly 300 normal family histories, many of them containing 50 to 100 individuals, with psychical and physical descriptions and entries as to ailments and causes of death. These are but, of course, the beginnings of a collection which one hopes and trusts will one day represent large samples of the physique, the mentality, the fertility and the disease of wide classes of the nation. The success of this sort of eugenics laboratory collection depends upon spreading widely three convictions: (1) that really useful results have flown, and will flow, from contributing to it; (2) that individuals, if appealed to frankly, will frankly tell the truth that lies within their knowledge; and (3) that the individual becomes a non-identifiable statistical unit before the record passes into the hands of the computer.²

Beyond the special collections of an individual laboratory there is already available a fair amount of published material. The United States has issued special censuses of the blind and of deaf-mutes. The Edinburgh Charity Organization Society has issued an excellent memoir on the home environment and the physique of 700 to 800 school children; above all, there are the registrar general's annual reports, the censuses, the reports of fever hospitals, of lunacy commissioners, and of the medical officers of asylums. Of some, but less value, are the reports of government commissions and the works of energetic, but statistically untrained, philanthropists like Charles Booth and Seebohm Rowntree. Important special researches, like that of Mr. Tocher on the insane of Scotland, or that now being carried out by Dr. Goring on

²The Eugenics Laboratory will gladly forward schedules (1) for general family history or (2) for special family abnormalities to any one interested in eugenic inquiry and willing to aid.

the convicts in his Majesty's prisons, serve to increase the total data already available or nearly so. While all eugenics workers crave for more material, and for better quality of material, yet there already exists ample material upon which to base the beginnings for our science.

If we turn from material to method, we note that except in so far as results for animals have application to man, we can not experiment on individuals, and our methods must, therefore, be those applicable to mass-observations—that is to say, those actuarial methods applied to biological data which we now term the methods of biometry. It is not needful for me to enlarge now or here on those methods. Suffice it to say that they appear to measure effectively the relationship between factors which are not causally linked together. For the explanation of what follows I would state that the arithmetical value of a certain quantity—the so-called coefficient of correlation—is chiefly used to measure this relationship. Starting when the quantities are absolutely independent with zero value, it rises with their complete causal relationship to unity. Table I. shows the sort of values taken by this coefficient for various kinds of association, when the variates lack the absolute dependence of pure causation.

TABLE I.

CORRELATION COEFFICIENTS

High Correlation 1 to .75

Right and left femur in man .....	.98
Finger and forearm in man .....	.85
Foot and forearm in man .....	.80
Middle phalanges of middle and little finger .....	.76

Considerable Correlation .75 to .5

Weight and stature in woman .....	.72
Finger and stature in man .....	.66
Vaccination and recovery in cases of smallpox .....	.60
Weight and strength of pull in man .....	.55

Moderate Correlation .5 to .25

Forearms of two brothers .....	.49
Deviations in bank reserve and discount rate .....	.37
Coat color in horse and its grandsire .....	.30
High barometer in Portugal and low barometer in Norway .....	.27

Low Correlation .25 to .00

Resemblance of Aphis to its grandmother .....	.24
Size of family, mother and daughter .....	.21
Duration of lives, mother and daughter .....	.15
Length and breadth of Parisian skulls .....	.05

From method I turn finally to illustrate the nature of the conclusions which have already been reached by eugenic inquiry. As a preliminary, I must picture for you what I think evolution means in the case of human societies.

There was a time when, thinking over the marvelous intellectual.

artistic, and physical development of ancient Greece, I could wonder how still more ample it might have been had there existed a master spirit or an imperious motive to weld those statelets into one great nation and check the rarely ceasing internal wars and personal feuds. Looking back—from what some of you may consider a less ethical, but I believe a more scientific standpoint—I now see a direct correlation between the achievements of Greece and the intensity of its intertribal struggles. The *pax romana* did not provide the Greek spirit with an atmosphere as bracing to either bodily or spiritual development, as the instability and storm which accompanied the earlier conditions.

The struggle of man against man, with its victory to the tougher and more crafty: the struggle of tribe against tribe, with its defeat for the less socially organized: the contest of nation with nation whether in trade or in war, with the mastery for the foreseeing nation, for the nation with the cleaner bill of health, the more united purpose of its classes, and the sounder intellectual equipment of its units: are not these phases of the struggle for existence the factors which have made for human progress, which have developed man from brute into sentient being? We have been told that “the cosmic process is opposed to the ethical”! But from the standpoint of science, is not the ethical the outcome of the cosmic? Are not the physique, the intellectuality, the morality of man, the product of that grim warfare between individual and individual, between society and society, and between humanity and nature, of which we even yet see no end? The ethical as the product of the cosmic process will indeed aid us when we pass outside the field of science. But standing well within the boundaries of that field, are men to cry like little children because the world is not “as it ought to be”?

Nach ewigen ehrnen
Grossen Gesetzen
Müssen wir alle
Unseres Daseyns
Kreise vollenden.

Nay, what has been rather man's method in mastering the physical universe? Has he not studied those brazen eternal laws, and guided the course of his being by that knowledge? Realize that the most valuable part of that knowledge is scarcely two hundred years old. And when we turn to biology—to the biological factors which control man's life and its relations to that of other organisms—are we not yet at the very dawn of discovery—a dawn whose actual storm-drifts foretell the coming flood of light?

Plato, in the Fifth Book of the “Laws,” describes what he terms a purification or purgation of the state. Permit me for my weakness, not yours, to cite it from Jowett's translation:

The shepherd or herdsman, or breeder of horses, or the like, when he has received his animals will not begin to train them until he has first purified them

in a manner which befits a community of animals; he will divide the healthy and unhealthy, and the good breed and the bad breed, and will send away the unhealthy and badly bred to other herds, and tend the rest, reflecting that his labors will be vain and without effect, either on the souls or bodies of those whom nature and ill-nurture have corrupted, and that they will involve in destruction the pure and healthy nature and being of every other animal, if he neglect to purge them away. Now, the case of other animals is not so important—they are only worth mentioning for the sake of illustration, but what relates to man is of the highest importance; and the legislator should make inquiries, and indicate what is proper for each in the way of purification and of any other procedure. Take, for example, the purification of a city—there are many kinds of purification, some easier and others more difficult; and some of them, and the best and most difficult of them, the legislator, if he be also a despot, may be able to effect; but he who, without a despotism, sets up a new government and laws, even if he attempt the mildest of purgations, may think himself happy if he can complete the work. The best kind of purification is painful, like similar cures in medicine, involving righteous punishment or inflicting death or exile in the last resort. For in this way we commonly dispose of great sinners who are incurable, and are the greatest injury to the whole state. But the milder form of purification is as follows: when men who have nothing, and are in want of food, show a disposition to follow their leaders in an attack on the property of the prosperous—these, who are the natural plague of the state, are sent away by the legislator in a friendly spirit as far as he is able, and this dismissal of them is euphemistically termed a colony. And every legislator should contrive to do this at once.

Now may we not claim Plato as a precursor of the modern eugenics movement? He grasped the intensity of inheritance, for he appeals to the herd and the flock; he realized the danger to the state of a growing band of degenerates, and he called upon the legislator to purify the state. Plato's purgation, if you will accept the view I have endeavored to lay before you to-day, has in fact hitherto been carried out by natural selection, by the struggle of man against man, of man against nature, and of state against state. This very cosmical process has so developed our ethical feelings that we find it difficult to regard the process as benign. A hundred years ago we still hung the greater proportion of our criminals or sent them for life across the seas, not even euphemistically terming it a "colony." We shut up our insane, making no attempt at cure; the modern system of hospitals and institutions and charities was scarcely developed; the physically and mentally weak had small chance of surviving and bearing offspring. There was a constant stern selection purifying in Plato's sense the state. The growth of human sympathy—and is not this one of the chief factors of national fitness?—has been so rapid during the century that it has cried Halt! to almost every form of racial purification. Is not this the real opposition which Huxley noticed between the ethical and cosmic processes? One factor—absolutely needful for race survival—sympathy, has been developed in such an exaggerated form that we are in danger, by suspending selection, of lessening the effect of those other factors which automatically purge the state of the degenerates in body and mind.

Do I therefore call for less human sympathy, for more limited charity, and for sterner treatment of the weak? Not for a moment;

we can not go backwards a single step in the evolution of human feeling! But I demand that sympathy and charity shall be organized and guided into paths where they will promote racial efficiency, and not lead us straight towards national shipwreck. The time is coming when we must consciously carry out that purification of the state and race which has hitherto been the work of the unconscious cosmic process. The higher patriotism and the pride of race must come to our aid in stemming deterioration; the science of eugenics has not only to furnish Plato's legislator with the facts upon which he can take action, but it has to educate public opinion until without a despotism he may attempt even the mildest purgation. To produce a nation healthy alike in mind and body must become a fixed idea—one of almost religious intensity, as Francis Galton has expressed it—in the minds of the intellectual oligarchy, which after all sways the masses and their political leaders.

Let me put before you a little more in detail the biological aspects of national growth. The Darwinian hypothesis asserts that the sounder individual has more chance of surviving in the contest with physical and organic environment. It is therefore better able to produce and rear offspring, which in their turn inherit its advantageous characters. Profitable variations are thus seized on by natural selection, and perpetuated by heredity.

Now if we are to apply these biological ideas to the case of man, we must have evidence (1) that man varies, (2) that these variations, favorable or unfavorable, are inherited, and (3) that they are selected.

Is it needful now to show that man varies? We not only know he varies, but the extent of variation in both man and woman has been measured by the biometric school in nearly two hundred cases. The variability within any single local race of man amounts from 4 or 5 to 15 to 20 per cent. of the absolute value of the character.

Secondly, are these variations inherited? Of this there is not the slightest doubt. They are not mere somatic fluctuations, but correspond to real geminal differences. The problem of inheritance is closely associated with that of the resemblance of members of the same stock, due caution being paid to the possibilities of environmental influence. Now we may separate the characters in which we are at present interested into three: (a) the physical, (b) the pathological and (c) the psychical.

Table II. gives us the resemblance between parent and offspring for a number of physical characters in man. Please note that the coefficient recorded is zero if there be no relationship and unity, if parent and offspring show an invariable relationship in the character under discussion. We see that the resemblance in the case of man lies between .4 and .5. It is about half-way up the correlation scale. Again the lower part of Table II. gives us corresponding measures of resemblance

between brethren for like characters; we notice that the resemblance lies between .5 and .6.

TABLE II.
INHERITANCE OF PHYSIQUE
Paternal Inheritance. Males Only

Method	Authority	Ages	Intensity
Family measurements:			
Stature.....	Pearson and Lee	Adults	.51
Span.....	“ “ “	“	.45
Forearm.....	“ “ “	“	.42
Family records:			
Eye color.....	“ “ “	“	.55

Fraternal Inheritance

Family measurements:			
Stature.....	Pearson and Lee	Adults	.51
Span.....	“ “ “	“	.55
Forearm.....	“ “ “	“	.49
Family records:			
Eye color.....	“ “ “	“	.52
School observations:			
Eye color.....	Pearson	Boy and boy	.54
School measurements: ³			
Head breadth.....	“	“ “ “	.59
Head length.....	“	“ “ “	.50
Head height.....	“	“ “ “	.55
Cephalic index.....	“	“ “ “	.49

Mean paternal value, .48. Mean fraternal value, .53.

For both parental and fraternal inheritance in man we find for physical characters much the same values as we find in the cases of cattle, horses and dogs. This is illustrated in Table III.

TABLE III.
PARENTAL INHERITANCE IN DIFFERENT SPECIES

Species	Character	Mean Value	No. of Pairs used
Man.....	Stature	.51	4,886
	Span	.48	4,873
	Forearm	.42	4,866
	Eye color	.50	4,000
Horse.....	Coat color	.52	4,350
Basset hound.....	Coat color	.52	823
Greyhound.....	Coat color	.51	9,279
Aphis.....	Right antenna	.44	368
	Frontal breadth	.47	
	Protopodite		
Daphnia.....	Body length		96
Mean.....	—	.48	

Turning now to diseased or pathological cases, we have at present only three types that have been dealt with. These are Mr. Edgar

³ Reduced to standard age of twelve years.

Schuster's results for the inheritance of deaf-mutism; Mr. Heron's results for the inheritance of the insane diathesis, and my own work on pulmonary tuberculosis. It is worth noting that these results are all first-fruits of Mr. Galton's foundation of a eugenics laboratory.

TABLE IV.
PATHOLOGICAL INHERITANCE

Condition	Investigator	Parental	Fraternal
Deaf-mutism.....	Schuster	.54	.73
Insanity.....	Heron	.58	.48
Pulmonary tuberculosis.....	Pearson	.50	.48
Mean value.....	—	.54	.56

Now it must be admitted at once that these diseased states are far harder to deal with than simple quantitative characters. Their treatment involves more assumptions, and the data are less trustworthy.

TABLE V.
SCHOOL OBSERVATIONS. RESEMBLANCE OF SIBLINGS
Physical Characters

Character	Boys	Girls	Boy and Girl
Health.....	.52	.51	.57
Eye color.....	.54	.52	.53
Hair color.....	.62	.56	.55
Curliness.....	.52	.52	.52
Cephalic index.....	.49	.54	.43
Head length.....	.50	.43	.46
Head breadth.....	.59	.62	.54
Head height.....	.55	.52	.49
Mean.....	.54	.53	.51

TABLE VI.
SCHOOL OBSERVATIONS. RESEMBLANCE OF SIBLINGS
Psychical Characters

Character	Boys	Girls	Boy and Girl
Vivacity.....	.47	.43	.49
Assertiveness.....	.53	.44	.52
Introspection.....	.59	.47	.63
Popularity.....	.50	.57	.49
Conscientiousness.....	.59	.64	.63
Temper.....	.51	.49	.51
Ability.....	.46	.47	.44
Handwriting.....	.53	.56	.48
Mean.....	.52	.51	.52

But from what I show in this table I think we may safely draw two conclusions: (a) the tendency to diseases of mind and body is inherited; (b) this inheritance may be slightly greater, it is hardly likely to be less, than the inheritance of quantitatively measurable physical characters.

I now turn to the inheritance of the psychical characters. Here again we tread on more difficult ground. On first investigating the problem myself I worked with school children, and for the following reasons. The teacher compares the individual with his general experience of many children; he thus

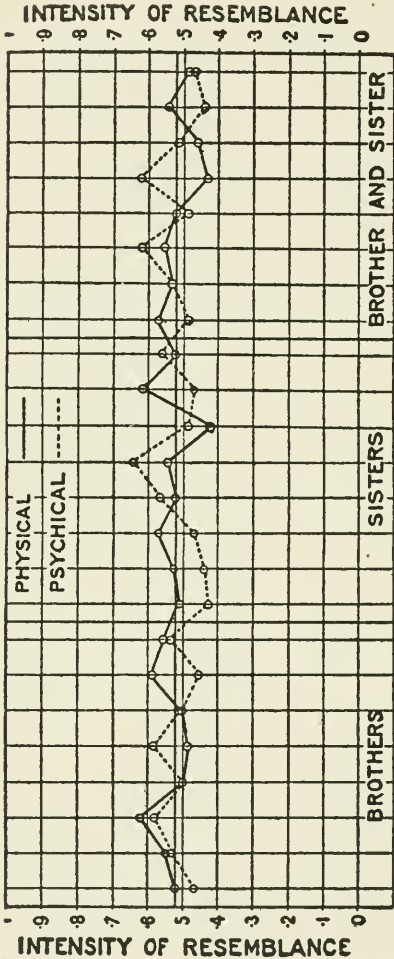


FIG. 3. COMPARISON OF RESEMBLANCE FOR PHYSICAL AND PSYCHICAL CHARACTERS.

approaches much more nearly an absolute standard than if we ask for an isolated return as to a single family from this or that relatively inexperienced recorder. Secondly, it is not often that we can find any data of the psychical characters of father and son taken at about the same period in life. If you will look at Tables V. and VI. and Fig. 3 you will see that I have not been able to discover any difference in intensity of inheritance between the psychical and physical characters in children.⁴ Mr. Schuster has been able to get over my difficulty at least for one character, that of ability in father and son as judged by the Oxford Class Lists. In a recent memoir published by the Galton Eugenics Laboratory he obtains the results given in Table VII. If we allow for an academic selection of intelligence, we reach values singularly close to those obtained for the physical characters. I have added some results of my own, not hitherto published, taken from my family record schedules. To sum up, there appears no doubt that good and bad physique, the liability to and the immunity from disease, the moral characters and the mental temperament, are inherited in man and with much the same intensity.

As a next stage, I point out—if it be needful to do so—that Figs. 4 and 5 show that those who live longest, and may be presumed to be

⁴The tables reproduced here are drawn from my Huxley lecture or other biometric memoirs.

TABLE VII.
 INHERITANCE OF ABILITY. MALE AND MALE
Paternal Inheritance

Method	Authority	Ages	Intensity
Oxford class lists.	Schuster	Adults	.49
Family records	Pearson	Adults	.58

Fraternal Inheritance

Oxford class lists.	Schuster	Adults	.56
Family records.	Pearson	Adults	.54
School class lists.	Schuster	Boys	.56
School observations.	Pearson	Boy and boy	.52

Mean paternal value, .54. Mean fraternal value, .54.

the healthiest, leave most offspring.⁵ One link still remains unproven: Are these variations subject to selection? Is the death rate in man a function of his constitution? Or does man fall in his youth or prime or dotage by the purely random bolt of death? The possibility of

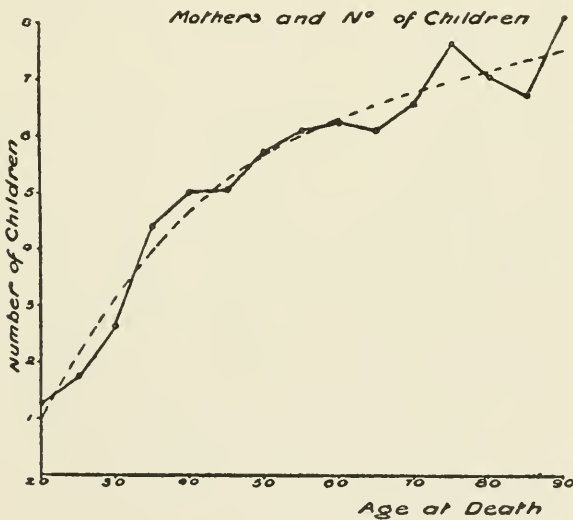


FIG. 4.

solving this last problem occurred to me when studying the inheritance of longevity. If longevity depended only on the physical constitution, we might expect it to be inherited at the same rate as other physical characters. I found it to be inherited always at a lesser rate. The difference could only be accounted for by the partly random character of death's aim. This was the key to measuring the proportion of the selective and non-selective death rates in man. Table VIII. gives you

⁵ The data are from the records of the Society of Friends, and show with little doubt an *unrestricted* birth rate.

the results. With these results it appears to me that Darwinism is clearly and definitely established for man.

It is not so many years ago since a distinguished statesman, speaking within the walls of this university, asserted that, "No man has ever seen natural selection at work." At that time all the criticism

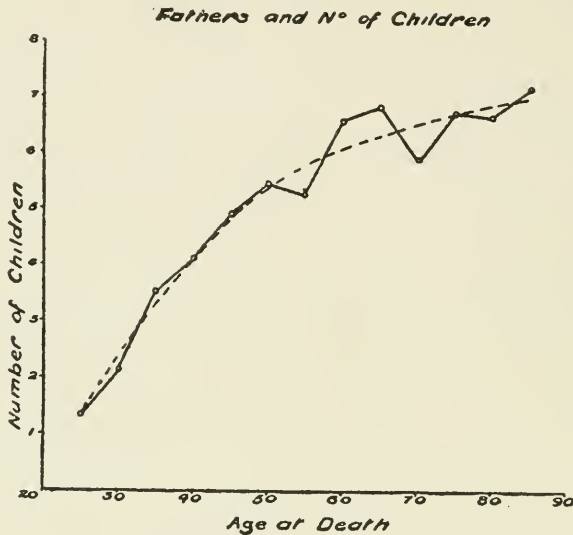


FIG 5.

possible seemed, "Every man who has lived through a hard winter, every man who has examined a mortality table, every man who has studied the history of nations, has *probably* seen natural selection at work." And thirteen years later I should add: The time has now come for statesmen to inquire whether natural selection is doing its work efficiently; that it applies to man no longer admits of question. Can it possibly be that agencies under the control of the legislator are suspending that Platonic purification of the state which in olden time natural selection worked almost automatically?

TABLE VIII.

NATURAL SELECTION IN MAN. PERCENTAGES OF DEATHS DUE TO SELECTIVE DEATH RATE

Deduced from Age at Death of Kindred

From Parental Heredity Data			From Fraternal Heredity Data		
Value	Selected %	Non-selected	Value	Selected %	Non-selected
.3	67.5	32.5	.4	84.1	15.9
.4	58.4	41.6	.45	79.3	20.7
.45	55.1	44.9	.5	75.2	24.8

Thus between 55 and 75 per cent. of deaths in the case of man are selective.

This is the next point concerning which eugenics may have something to tell us. In order that natural selection should be suspended, it is not sufficient to reduce the selective death rate; it is necessary that the relative fertility of the unfit should be higher than that of the fit. If the unfit variations leave to any state their heritage of unfitness, what can save that state from degeneracy, what hinder a catastrophe when that state has to prove its only title-deed to seizin of the earth?

TABLE IX.
FERTILITY IN PATHOLOGICAL AND NORMAL STOCKS
Pathological

	Authority	Nature of Marriage	Size of Family
Deaf-mutes, England.....	Schuster	Probably completed	6.2
Deaf-mutes, America.....	Schuster	“ “	6.1
Tuberculous stock	Pearson	“ “	5.7
Albinotic stock	Pearson	“ “	5.9
Insane stock.....	Heron	“ “	6.0
Edinburgh degenerates.....	Eugenics Lab.	Incomplete	6.1
London mentally defective.....	“ “	“	7.0
Manchester mentally defective....	“ “	“	6.3
Criminals	Goring	Completed	6.6
<i>Normal</i>			
English middle class.....	Pearson	15 years at least— begun before 35	6.4
Family records	Pearson	Completed	5.3
English intellectual class	Pearson	All completed marriages	4.7
Working class N. S. W.....	Powys	Completed	5.3
Danish professional class.....	Westergaard	15 years at least	5.2
Danish working class.....	Westergaard	25 years at least	5.3
Edinburgh normal artizan.....	Eugenics Lab.	Incomplete	5.9
London normal artizan	“ “	“	5.1
American graduates.....	Harvard	Completed ?	2.0
English intellectuals	S. Webb	Said to be completed	1.5

All childless marriages are excluded except in the last two cases. Inclusion of such marriages usually reduces the average by ½ to 1 child.

In Table IX. I have placed the fertility of deaf-mute, tuberculous, criminal and insane stocks, and below them the fertility of more normal classes in the community. It is at once obvious that degenerate stocks under present social conditions are not short-lived, they live to have more than the normal size of family. Natural selection is largely suspended, but not the inheritance of degeneracy nor the fertility of the unfit. On the contrary, there is more than a suspicion of the suspension of the fertility of the fit. If further evidence be needful, look at the results in Table X. for the correlation between all that makes for unfitness and the number of children per married woman under fifty-five. Mr. Heron has indeed shown us that the survival of the unfit is a marked characteristic of modern town life. Every condition

which makes for bad nurture as well as bad nature seems to emphasize the birth rate.

As we have found conscientiousness is inherited, so I have little doubt that the criminal tendency descends in stocks. To-day we feed our criminals up, and we feed up the insane, we let both out of the prison or the asylum "reformed" or "cured" as the case may be, only after a few months to return to state supervision, leaving behind them the germs of a new generation of deteriorants. The average number of crimes due to the convicts in his majesty's prisons to-day is ten apiece. We can not reform the criminal, nor cure the insane

TABLE X.

CORRELATION OF BIRTH RATE MEASURED ON WIVES OF REPRODUCTIVE AGES WITH SOCIAL AND PHYSICAL CHARACTERS OF POPULATION OF LONDON

For 1901 Census. David Heron

<i>Birth Rate</i>	Characters Correlated	Correlation Coefficient
	With males engaged in professions	— .78
	With female domestics per 100 females	— .80
	With female domestics per 100 families	— .76
	With general laborers per 1,000 males	+ .52
	With pawnbrokers and general dealers per 1,000 males	+ .62
	With children employed, ages 10-14	+ .66
	With persons living more than 2 in a room	+ .70
	With infants under 1 year dying per 1,000 births	+ .50
	With death from phthisis per 100,000	+ .59
	With total number of paupers per 1,000	+ .20
	With number of lunatic paupers per 1,000	+ .34
<i>Infant Mortality</i>		
	With children aged 2-4	+ .59
	“ “ 5-14	+ .54
	“ “ 13-15	+ .34
	(per 100 wives)	

These last results show that the infantile mortality of the fertile classes does not compensate for their predominant fertility.

from the standpoint of heredity; the taint varies not with their moral or mental conduct. These are products of the somatic cells; the disease lies deeper in their germinal constitution. Education for the criminal, fresh air for the tuberculous, rest and food for the neurotic—these are excellent, they may bring control, sound lungs, and sanity to the individual; but they will not save the offspring from the need of like treatment, nor from the danger of collapse when the time of strain comes. They can not make a nation sound in mind and body, they merely screen degeneracy behind a throng of arrested degenerates. Our highly developed human sympathy will no longer allow us to watch the state purify itself by aid of crude natural selection. We see pain and suffering only to relieve it, without inquiry as to the moral character of the sufferer or as to his national or racial value. And this is right—no man is responsible for his own being; and nature and

nurture, over which he had no control, have made him the being he is, good or evil. But here science steps in, crying:

Let the reprieve be accepted, but next remind the social conscience of its duty to the race. No nation can preserve its efficiency unless dominant fertility be associated with the mentally and physically fitter stocks. The reprieve is granted, but let there be no heritage if you would build up and preserve a virile and efficient people.

Here, I hold, we reach the kernel of the truth which the science of eugenics has at present revealed. The biological factors are dominant in the evolution of mankind; these, and these alone, can throw light on the rise and fall of nations, on racial progress and national degeneracy. In highly civilized states, the growth of the communal feeling—upon which indeed these states depend for their very existence—has not kept step with our knowledge of the laws which govern race development. Consciously or unconsciously we have suspended the racial purgation maintained in less developed communities by natural selection. We return our criminals after penance, our insane and tuberculous after “recovery,” to their old lives; we leave the mentally defective flotsam on the flood-tide of primordial passions. We disregard on every side these two great principles: (*a*) the inheritance of variations, and (*b*) the correlation in heredity of unlike imperfections.⁶ The statesman, as usual, is inert, waiting for the growth of popular opinion. Doctors, we are told, do not believe in heredity. If that be so, they have small idea of the most plentiful harvest yet reaped by modern science. The philanthropist looks to hygiene, to education, to general environment, for the preservation of the race. It is the easy path, but it can not achieve the desired result. These things are needful tools to the efficient, and passable crutches to the halt; but at least on one point Mendelian and biometrician are in agreement—there is no hope of racial purification in any environment which does not mean selection of the germ.

If I speak strongly, it is because I feel strongly; and the strength of my feeling does not depend on the few facts I have brought before you to-day. It would be possible to paint a lurid picture—and label it race-suicide. That is feasible to any one who has seen, even from afar, the nine circles of that dread region which stretches from slum to reformatory, from casual ward and stew to prison, from hospital and

⁶We are at present only reaching light on what is a very important principle, namely, that stocks exist which show a general tendency to defect, taking one form in the parent, another in the offspring. Neuroses in the parents become alcoholism or insanity in the offspring; mental defect may be correlated with tuberculosis, albinism with imbecility; and one type of visual defect in the father be found associated with a second in the son. We can not at present give this fact scientific expression, but it would appear that there is something akin to germinal degeneracy which may show itself in different defects of the same organ or in defects of different organs. The solution, perhaps, lies in a tendency to general defect in the gamete. Even now, I doubt whether it is absolutely unscientific to speak of a general inheritance of degeneracy.

*Distribution of Tuberculous Members
in Family*

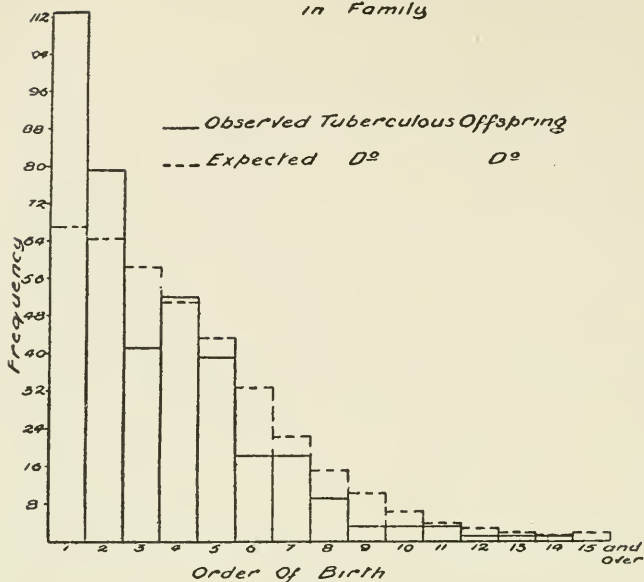


FIG. 6, a.

*Distribution of Insane Members
in Family*

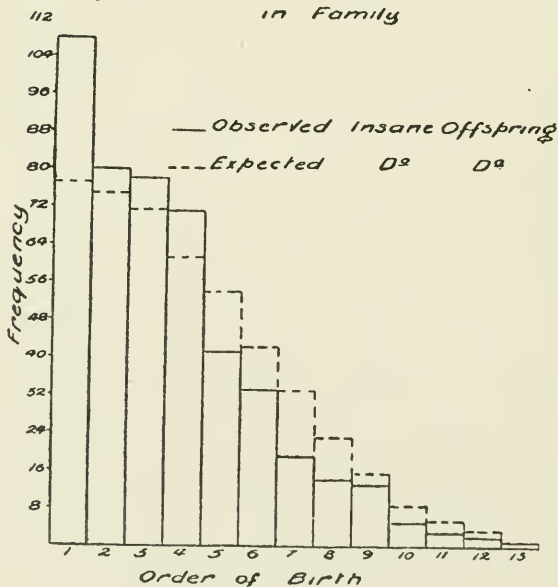


FIG. 6, b.

sanatorium to asylum and special school; that infernal lake which sends its unregarded rivulets to befool more fertile social tracts. But the scope of eugenics is not to stir the social conscience by an exaggerated

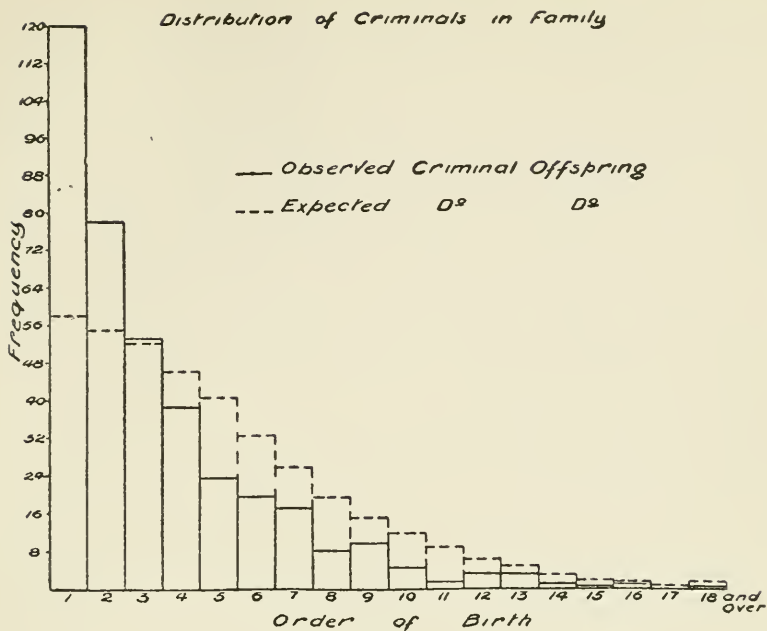


FIG. 6, c.

picture of racial dangers. Those dangers are not wholly recent, if they are increasing in intensity; they are not peculiar to England, as a brief acquaintance with French and German conditions will suffice to show. Nay, even in the new world men are awaking to the peril which high civilizations risk from their treatment of degenerates. What we leave to private effort, the establishment of a eugenics laboratory, they propose in the United States to do by a government office. The American proposal to establish a laboratory in the Department of the Interior for the study of the abnormal classes and the collection of sociological and pathological data, has only one, but that a grave defect. No eugenics laboratory which confines its attention to the study of the abnormal can fulfil its functions. The positive side is as important as the negative side, and the application of the laws of inheritance to the betterment of the good is as vital as and far more likely to inspire us with hope of achievement than concentrating our investigations on the excision of the bad.

If we realize the antinomy which eugenics brings to our notice between high civilization and racial purgation, we ask: How can the dominant fertility of the fitter social stocks be maintained when natural selection has been suspended? I do not think any wise man would be prepared with a full answer to this question to-day. There is no sovereign remedy for degeneracy. Every method is curative which tends to decrease the fertility of the unfit and to emphasize that of the fit.

We may find it difficult to define the socially fit, although physique and ability will carry us far; but when we turn to the habitual criminal, the professional tramp, the tuberculous, the insane, the mentally defective, the alcoholic, the diseased from birth or from excess, there can be little doubt of their social unfitness. Here every remedy which tends to separate them from the community, every segregation which reduces their chances of parentage, is worthy of consideration. Strange as it may seem, we are not much beyond the cure suggested by Plato—what is “euphemistically termed a colony,” for the degenerates of each sex. The duty of the man of science is to find out the law, and if possible waken the conscience of his countrymen to its existence. It is the function of the statesman to discover the feasible social remedy which is not at variance with that law.

But, thus far, I have touched on only one side of the problem, the reduction in bad stock. Is not something more to be insisted upon with regard to the increase of good stock? Have we not treated the birth of children as something that concerned the individual and not the state? May not a source of racial greatness lie in a national spirit, like that of Japan, which demands the healthy able child from fitting parents, and looks with sinister eye on those who provide the state with the halt and diseased? I may have overlooked the point, but I have not noticed that this first principle of duty to the race, of national morality, has been fully insisted upon by our ethical writers. I have often heard false pride of ancestry condemned, but I have not seen the true pride of ancestry explained and commended. Surely the man who is conscious that he comes of a stock sound in body, able in mind, tested in achievement, and who knows that, mating with like stock and maintaining himself in health, he will hand down that heritage to his children—surely such a man may have a legitimate pride in ancestry, and is worthy of honorable mention in eugenic records? It seems to me that those who have the welfare of the nation, and our racial fitness for the world-struggle, at heart must recognize that this is the ideal which the racial conscience demands of its saner members.

A clean body, a sound if slow mind, a vigorous and healthy stock, a numerous progeny, these factors were largely representative of the typical Englishman of the past; and we see to-day that one and all these characteristics can be defended on scientific grounds; they are the essentials of an imperial race.

As we have found an antinomy between high civilization and race purification by natural selection, so there appears to be a corresponding antagonism between individual comfort and race welfare. It is again the tendency of higher civilization to suspend the more drastic phases of the struggle for existence and the survival of the fitter. The man of education, or made position, says “the chances of my children are better if I have but few of them,” and we reach the startling condition

of America, where the classes of ability—the classes which take as their standard an academic education—are not reproducing themselves, their average number of offspring being less than two; we reach the state of affairs which Mr. Sydney Webb tells us is demonstrable in another intellectual circle in this country, an almost childless population of non-inherited ability. And against this we have to set the maximum fertility which is reached by the degenerate stocks! Individual welfare and race welfare, are they really as opposed as they appear? Is it true insight to consider that the fewer children the better is their prospect in life? I can not think that the time has come when the family is no longer an effective social unit. Is the family of two really in a stronger condition to face the world? Is there not mutual help and strength in kinship, and as age comes on must the old and feeble be left to the care of strangers? Eugenically Mr. Powys, in his fine memoir on fertility and duration of life in New South Wales,⁷ has shown that in Australia the longest-lived women are the mothers neither of small nor of inordinately large families. They are the mothers of five to six children. Eugenically we have shown that the two or three first-born members of a family are more liable to insanity (Heron), tuberculosis (Pearson), criminality (Goring) and mental defect.⁸ Fig. 6 will illustrate this. The excess of pathological cases among the earlier born is very significant. Economically, is it not true that if six degenerates are born to two, and not six, sound men and women, those two will have to do triple work to provide—in prison, asylum, institution and hospital—for this mass of the incompetent? I am not sure that a strong case could not be made out against the small family even on the basis of individual welfare! But I would rather appeal on this point to race instinct and to the social conscience. The progress of the race inevitably demands a dominant fertility in the fitter stocks. If that principle be not recognized as axiomatic by the mentally and bodily fit themselves, if the statesman does not accept it as a guide in social legislation, then the race will degenerate, until, sinking into barbarism, it may rise again through the toilsome stages of purification by crude natural selection. I am not pessimistic in this attitude. I know that the English people has been aroused to self-consciousness more than once in its history, and I believe that now it can be brought to realize that safety lies in a conscious race-culture. If race feeling can be appealed to by men trained to see the bearing of great biological laws on human growth, then we shall not create a mere passing wave of national emotion conveniently satisfied by the appointment, dead before the report, of a royal commission. The time seems upon us when the biological sciences shall begin to do for man what the

⁷ *Biometrika*, Vol. IV., pp. 233-92.

⁸ It seems to me that here science has a word to say with regard to reform of a hereditary peerage.

physical have done for more than a century; when they shall aid him in completing his mastery of his organic development, as the physical sciences have largely taught him to control his inorganic environment. To bring this about we need above all two factors. First: a knowledge of inheritance, variation, selection and fertility in man, and the relation of these results to racial efficiency. To this special branch of biology, Francis Galton has given the name of the science of national eugenics, and in founding the Francis Galton Laboratory for National Eugenics in the University of London he has been the pioneer in asserting that even from the academic standpoint "the proper study of mankind is man." Eighty years ago there were no physical laboratories in the universities of this country, sixty years ago there were no physiological laboratories, thirty years ago there were no engineering laboratories. To-day there is only one laboratory for national eugenics. I believe that every university twenty years hence will offer its students training in the science that makes for race-efficiency and in the knowledge which alone can make a reality of statecraft. The eugenics laboratory then will require no apology, it will be too well recognized a part of university equipment. The second factor which seems to me needful is an altered tone with regard to those phases of our sexual life upon which the health and welfare of the nation as a whole so largely depend. In this matter I think we can learn from the spirit of our youngest allies, the Japanese, and from the practise of our oldest allies, the Jews. With both, race-preservation and race-betterment have assumed the form of a religious cult. And one aim of my lecture to-day is that I may appeal to the younger members of my audience, on whom responsibility for forming opinion will shortly fall, to weigh these things well, for they touch closely our national safety. On the one hand, I do not raise an alarmist picture of our coming decadence, nor, on the other hand, would I leave you without insisting that there is grave occasion for earnest thought. I would raise interest in a new and, I believe, potent branch of science; I would call for a strengthening of racial conscience, and a scientific basis for conduct, as our growing civilization stems natural selection as the purifier of the state. Thus it is that eugenics passes from science into practise, from knowledge to a creed of action. This can not be expressed better than by Francis Galton's concluding words in his "Eugenics as a Factor of Religion":

Eugenic belief extends the function of philanthropy to future generations, it renders its actions more pervading than hitherto, by dealing with families and societies in their entirety, and it enforces the importance of the marriage covenant by directing serious attention to the probable quality of the future offspring. It sternly forbids all forms of sentimental charity that are harmful to the race, while it eagerly seeks opportunity for acts of personal kindness, as some equivalent to the loss of what it forbids. It brings the tie of kinship into prominence and strongly encourages love and interest in family and race. In brief, eugenics is a virile creed, full of hopefulness, and appealing to many of the noblest feelings of our nature.

PETER KALM'S "TRAVELS"

BY SPENCER TROTTER
SWARTHMORE COLLEGE

A STUDENT of our early colonial history once remarked to me that we should have lived some two hundred years before our time, then we might have thoroughly enjoyed the country. By "country" he meant the natural, primitive condition of the land as it appeared to the first generation of Europeans born on its shores. It was far from being the inhospitable wilderness that their fathers had known. Homes of some comfort stood in the midst of cleared land; the fields yielded an abundant harvest; flourishing young towns and the king's highway gave to the new country a semblance of old-world civilization. And yet, withal, the ancient woods and the wild life were but a bow-shot from its door-steps.

This observation of my friend makes a strong appeal to the imagination of those of us who love simple ways and nature undisturbed. We may voice the poet's regret that

The world is too much with us,

but in truth it would doubtless be a great hardship if we should find ourselves, by some trick of a fairy godmother, back in those primitive days. A man's life is so largely made up of the things of the mind that it is the picture of the thing that makes for happiness far more than the reality.

The past is a fine canvas for our pictures. The pigments of fancy blend in pleasing effects, and distance in time as well as in space lends its enchantment. Many things are potent to suggest these pictures—the faded leaves of a diary, a bit of finery, the site of some long-forgotten house, an old book—trifles light as air that turn the hard lines of a modern scene into the soft, hazy light of the past.

The peculiar charm of an old book is the atmosphere that pervades it. Its pages may contain nothing of interest, even to the most curious reader, but with the lapse of time the dullest volume acquires a certain distinctive character. An old book breathes of the past; the scent of its stained and musty leaves penetrates into the dim chambers of the mind where fancy slumbers. And when fancy stirs and awakens its neighbor, long-forgotten memory, mayhap we have here the reason for this endearing quality of old things, for who knows what shreds of ancestral memories were wrapped in the bundle of our inheritances.

This flotsam and jetsam of the literary past, drifted on to the upper shelves and into out-of-the-way places, may yield some bit of treasure—some record vivid with the life of old days and of places long since blotted out.

Among such driftwood is occasionally to be found a rare fragment of Americana—the “Travels into North America,” by Peter Kalm. It is a quaint old book with the observations and reflections of an inquisitive naturalist who visited this country in the middle of the eighteenth century. There is no attempt at style or literary finish of any sort—it is the plain narrative of a man whose interests were by no means confined to natural history. The book is charming in the desultory treatment of its subject matter—in its utter lack of logical arrangement. In one place we read of “cyder” making, and in the very next paragraph the author abruptly launches forth in a dissertation on “a certain quadruped which is pretty common, not only in *Pensylvania*, but likewise in other provinces, both of *South* and *North America*, and goes by the name of *Polecat* among the *English*. In *New York* they generally call it *Skunk*.” In another place some peculiarity in the marriage of widows is followed by a dissertation on divers remedies used against the toothache.

Kalm was omnivorous as to facts. He meant to tell everything about the new country, and sets this forth in the following remarkable title—

TRAVELS
INTO
NORTH AMERICA;
CONTAINING
ITS NATURAL HISTORY, AND
A circumstantial Account of its Plantations
and Agriculture in general,
WITH THE
CIVIL, ECCLESIASTICAL AND COMMERCIAL
STATE OF THE COUNTRY,
The MANNERS of the INHABITANTS, and several curious
and IMPORTANT REMARKS on various Subjects.

A perusal of the book fully justifies this title. One is convinced that “no circumstance interesting to natural history or to any other part of literature has been omitted.” The book was first published at Stockholm in 1753 under the title “*En Resa Til Norra America*,” and it was subsequently translated into both German and English. The English translation, edited by the naturalist, John Reinhold Forster, was first published at London in 1772, in three volumes, and is dedicated to the Hon. Daines Barrington, the same to whom Gilbert White of Selborne addressed so many of his letters.

Kalm, who held the position of “Professor of Economy in the Uni-

versity of Aobo in Swedish Finland," was sent out at the instance of the Royal Academy of Sciences at Stockholm to make "such observations and collections of seeds and plants as would improve the *Swedish* husbandary, gardening, manufactures, arts and sciences." Iceland and Siberia were first proposed as the countries to be explored for this purpose, but Linnaeus "thought that a journey through *North America* would be yet of more extensive utility." What Sweden gained by this change of plan we do not know, but the literary and scientific world of that day gained much, and we of to-day—lovers of old books and quaint recitals—find great store of pleasure in these pictures of the past.

Kalm's book is full of local color and redolent of the soil and the air of the country. The simplicity and directness of statement put one at once in sympathy with the man. His personality is in every page, but there is no striking of the literary attitude. He is entirely simple-minded, almost child-like—a gentle, companionable man. Listen to this naïve rehearsal on the first day of his setting foot ashore at Philadelphia:

I found that I was now come into a new world. Whenever I looked to the ground, I everywhere found such plants as I had never seen before. When I saw a tree, I was forced to stop, and ask those who accompanied me, how it was called. The first plant which struck my eyes was an *Andropogon*, or a kind of grass, and grass is a part of Botany I always delighted in. I was seized with terror at the thought of ranging so many new and unknown parts of natural history. . . . At night I took up lodging with a grocer who was a quaker, and I met with very good, honest people in this house, such as most people of this profession appeared to me; I and my *Yungstraem*, the companion of my voyage, had a room, candles, beds, attendance, and three meals a day, if we chose to have so many, for twenty shillings per week in *Pensylvania* currency. But wood, washing and wine, if required, were to be paid for besides.

Kalm had numerous letters of recommendation—

Mr. *Benjamin Franklin*, to whom *Pensylvania* is indebted for its welfare, and the learned world for many new discoveries in electricity, was the first who took notice of me, and introduced me to many of his friends. He gave me all necessary instructions, and shewed me his kindness on many occasions.

A Swede himself, Kalm naturally spent much of his time among the Swedes, descendants of the first Swedish settlers on the Delaware. At the village of Raccoon on the New Jersey shore, he sojourned with his brethren for many weeks during the winter and spring of 1749. The village has long since disappeared; the place where it once stood is now not certainly known, but Raccoon Creek still falls into the Delaware, nearly opposite the Pennsylvania town of Chester, and the searcher after old sites may spend some pleasant hours, if only with the haunting sense of the vanished hamlet that once stood somewhere in this neighborhood. Here Kalm gained much information from the

mouths of old Swedes who remembered the land in the earlier days of its settlement.

The first houses that the Swedes built consisted of but one little room, with the door so low that one had to stoop in order to get in. "As they had brought no glass with them, they were obliged to be content with little holes, before which a movable board was fastened." The cracks and crannies were stopped with clay. Clay was also used, in many instances, in the construction of their chimneys.

Before the *English* came to settle here, the *Swedes* could not get as many cloaths as they wanted; and were therefore obliged to make shift as well as they could. The men wore waistcoats and breeches of skins. Hats were not in fashion; and they made little caps, provided with flaps before. They had worsted stockings. Their shoes were of their own making. Some of them had learnt to prepare leather, and to make common shoes with heels; but those who were not shoemakers by profession, took the length of their feet, and sewed the leather together accordingly; taking a piece for the sole, one for the hind-quarters, and one more for the upper-leather. At that time, they likewise sowed flax here, and wove linen cloth. Hemp was not to be got; and they made use of flaxen ropes and fishing tackle. The women were dressed in jackets and petticoats of skins. Their beds, excepting the sheets, were skins of several animals; such as bears, wolves, etc.

Such "superfluities" as tea, coffee and chocolate were unknown to these first settlers on the Delaware, but rum they had at "moderate price" and "sugar and treacle they had in abundance. . . . Almost all the *Swedes* made use of baths; and they commonly bathed every *Saturday*." Their carts must have been remarkable constructions, the wheels sawed from thick pieces of the liquidambar tree.

These old Swedes had a small idea of the value of land and sold large tracts to English settlers for a mere song. One old Swede told Kalm that his father sold an estate, which at the time of Kalm's visit was reckoned at three hundred pounds value, "for a cow, a sow and a hundred gourds."

Kalm was evidently much impressed by the spirit of liberty that prevailed amongst the people. Speaking of the decrease of certain wild birds, as compared with their former abundance, he says:

But since the arrival of great crowds of *Europeans*, things are greatly changed; the country is well peopled, and the woods are cut down; the people increasing in this country, they have by hunting and shooting in part extirpated the birds, in part scared them away; in spring the people still take both eggs, mothers and young indifferently, because no regulations are made to the contrary. And if any had been made, the spirit of freedom which prevails in the country would not suffer them to be obeyed.

In another place he refers to the freedom displayed in taking fruit from the orchards.

The orchards, along which we passed today, were only enclosed by hurdles. But they contained all kinds of fine fruit. We wondered at first very much

when our leader leaped over the hedge into the orchards, and gathered some agreeable fruit for us. But our astonishment was still greater when we saw that the people in the garden were so little concerned at it, as not even to look at us. But our companion told us, that the people here were not so exact in regard to a few fruits, as they were in other countries where the soil is not so fruitful in them. We afterwards found very frequently that the country people in *Sueden* and *Finland* guarded their turnips more carefully, than the people here do the most exquisite fruits.

Among the many customs of the people which Kalm noted are the following curious passages relating to marriage—

There is a great mixture of people of all sorts in these colonies, partly of such as are lately come over from *Europe*, and partly of such as have not yet any settled place of abode. Hence it frequently happens that when a clergyman has married such a couple, the bridegroom says he has no money at present, but would pay the fee at the first opportunity; however, he goes off with his wife, and the clergyman never gets his due. This proceeding has given occasion to a custom which is now common in *Maryland*. When the clergyman marries a very poor couple, he breaks off in the middle of the *Liturgy*, and cries out, *Where is my fee?* The man must then give the money, and the clergyman proceeds; but if the bridegroom has no money, the clergyman defers the marriage till another time, when the man is better provided. People of fortune, of whom the clergyman is sure to get his due, need not fear this disagreeable question, when they are married. . . . There is a very peculiar diverting custom here, in regard to marrying. When a man dies, and leaves his widow in great poverty, or so that she can not pay all the debts with what little she has left, and that, notwithstanding all that, there is a person who will marry her, she must be married in no other habit than her shift. By that means, she leaves to the creditors of the deceased husband her cloaths, and everything which they find in the house. But she is not obliged to pay them anything more, because she has left them all she was worth, even her cloaths, keeping only a shift to cover her, which the laws of the country cannot refuse her. As soon as she is married, and no longer belongs to the deceased husband, she puts on the cloaths which the second has given her. The *Swedish* clergymen here have often been obliged to marry a woman in a dress which is so little expensive, and so light.

There are various references in Kalm's book to the aboriginal inhabitants of the country, though at the time of his visit the Indians had retired from the immediate vicinity of the seaboard. "It is very possible," says Kalm, "for a person to have been at *Philadelphia* and other towns on the sea shore for half a year together, without so much as seeing an *Indian*." Most of Kalm's observations concerning the natives, their manners, customs and food, are at second hand, but may be regarded as fairly reliable, his information being obtained from the older Swedes, who, in the earlier days of the settlement, had been well acquainted with the Indian people that dwelt by the Delaware.

What pleases the reader most in Kalm's book, I think, is the general picture of the country and the local color which he gets from the scattered observations and descriptions throughout the pages. Naturally Kalm was much impressed with the extent of forest in this new

world. Furthermore he was a botanist, and had an eye for the various kinds of trees, the remarks upon which, and upon the great variety of plants that he observed and collected, occupy a considerable portion of the narrative. He tells us in one place that grass formerly grew in the woods which were then quite open, with little or none of the underwood growth which characterize our woodlands to-day. The settled parts of the country must have had a wild and shaggy look, even in Kalm's time, for he speaks of the stumps of trees in the corn-fields—a real backwoods' picture—and notes that the farms were widely separated from one another:

The greatest part of the land, between these farms so distant from each other, was overgrown with woods, consisting of tall trees. However, there was a fine space between the trees, so that one could ride on horseback without inconvenience in the woods, and even with a cart in most places; and the ground was very plain and uniform at the same time. . . . In some parts of the country the trees were thick and tall, but in others I found large tracts covered with young trees, only twenty, thirty, or forty years old; these tracts, I am told, the *Indians* formerly had their little plantations in. . . . The woods consisted chiefly of several species of oak, and of hickory.

An old Swede, Nils Gustafson by name, ninety-one years of age, told Kalm that

he could very well remember the state of the country, at the time when the *Dutch* possessed it, and in what circumstances it was before the arrival of the *English*. He added, that he had brought a great deal of timber to *Philadelphia*, at the time it was built. He still remembered to have seen a great forest on the spot where *Philadelphia* now stands.¹

Kalm had a practical turn of mind. Being a professor of "Economy," he was at all times on the look-out for the uses of things. Whatever contributed to human welfare seemed to him of the first moment. What a particular plant or tree yielded in the way of dyes, or food, or timber, or remedies against sickness; the nature of soils, the qualities of rocks and stones for building purposes; the thrift, or want of it, on the part of the people; how they clothed and housed themselves; how prolific they were, what they ate, how they cooked their food, how they cared for their stock and crops—all such matters find a conspicuous place in his pages. And so he goes rambling delightfully on—describing and commenting upon everything that he saw, or even heard of—here about wine-making, or fences, or soring-houses; there about some curious custom, or remarkable occurrence. He was forever putting a question—"quere," as he called it—"where did the Swedes here settled get their several sorts of corn, and likewise their fruit-trees and kitchen-herbs?" "Whence did the *English* in *Pensylvania* and *New Jersey* get their cattle?" "Where did these *Swallows*

¹ According to Heckwelder, this site was called by the Indians *Kúequenáku*, which means the "grove of the long pine trees."

[Chimney Swifts] build their nests before the *Europeans* came and made houses with chimneys?" He had much to say about the more familiar birds² and beasts that he met with and heard of—their peculiarities and habits, and occasionally a grotesque story concerning some one of them. The weather, too, took up a large share of his attention, and he appears to have kept a careful record which is inserted as an appendix to the second volume of the translation.

Kalm constantly refers to his friend Dr. Linnæus, who evidently held the author of the "Travels" in high esteem. The generic name of our laurels—*Kalmia*—was bestowed by the great naturalist in honor of his humble friend, and Kalm, in speaking of the laurel, refers to this fact. John Bartram, the first American botanist, and whose house, built in 1731, is still standing, surrounded by its delightful old garden, was another to whom Kalm constantly refers in terms of friendship. His intercourse with Bartram and with Benjamin Franklin during his sojourn in Philadelphia was evidently a great source of satisfaction to Kalm, for he makes frequent allusion to his visits to and conversations with these worthies.

The "Travels" were not confined to the neighborhood of Philadelphia, though the author spent much of his time in this vicinity. He visited New York on one or two occasions, and made an arduous journey to Montreal, by way of the Hudson, and was at one time in some danger from an attack by the Iroquois. He seemed particularly struck with the French women of Montreal—their looks, dress, and good manners—and draws some rather invidious comparisons between them and their English sister residents. "In their knowledge of œconomy," he says, "they greatly surpass the *English* women in the plantations, who indeed have taken the liberty of throwing off the burthen of housekeeping upon their husbands, and sit in their chairs all day with folded arms." These remarks brought forth a defensive foot-note on the part of the English translator.

The "Travels into North America" is to be read in a spirit of simplicity, for in such a spirit it was conceived. One reads it as he reads "The Compleat Angler," or "The Natural History of Selborne," or Sir Thomas Browne—books that exhale a perennial fragrance, having their roots deep in the soil of things personal.

² See article by the writer in the *Auk*, Vol. XX., No. 3, July, 1903.



HUSAVIK.



SNOW MOUNTAINS ON SKJALFANDI.

A TRIP AROUND ICELAND

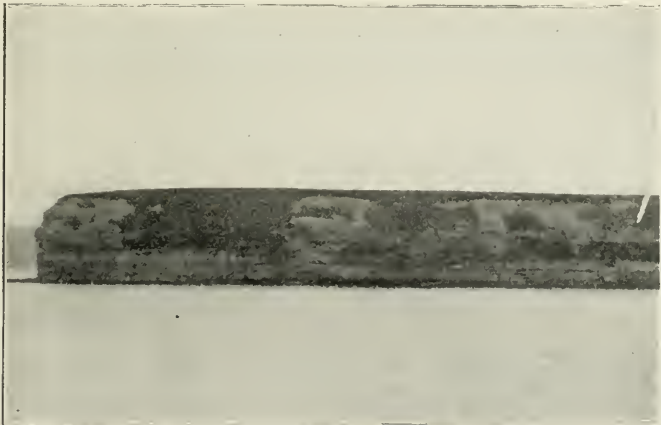
BY L. P. GRATACAP

AMERICAN MUSEUM OF NATURAL HISTORY

II

THEN came Husavik, a large village looking amazingly well with its extended domiciles cleanly cut in the sunlight, at the base of some old crater cone, which Professor Gourdon told us repeated the worn-down volcanic stocks of Auvergne, which that notable pioneer Guettard first pointed out were igneous accumulations. And how bare it all was! Two wild white swans suddenly swept through the foreground. We dropped off a *sysselman* here: a kind of local magistrate, governor, collector of the port, friend of the fatherless and widow, and general *Pooh-bah* who raised his hat as he left us as if he expected us to recognize his official importance. Icelanders pay the most formal respect to each other and doffing his hat for a person of a large acquaintance must, in so uncertain a climate, insure a popular man a permanent cold in his head. The *sysselman*, who thus returned to his domain, had an earnest mien, and was typical of the strong, resolute and intelligent temperament and mind of these boreal democrats.

We turned westward again over the *Skjalfandi*, the broad bay west of Husavik, toward the beautiful range of mountains on the opposite shore, the Viknafjöll hills. As they came near to hand in the transfiguring light of the setting sun, they were revealed as a series of enfiling peaks standing up behind each other, with the pockets between them spotted with snow, while snow-fields like spotless rugs hung low down on their steep flanks. They grew upon our eyes in



FLAT ISLAND NEAR HUSAVIK.



AKREYRI, DOCK FOR STEAMER.

magnificence and beauty, they seemed to exhale a spell in that northern latitude that drew us to them, pressed close upon the gunwales of our ship, in wondering silence.

The weathering, and subaerial erosion here was most pronounced—and the range seemed clearly older than the east-coast rocks. The sides of the mountains plunged with unhesitating precipitancy into the water. The beds composing them had variable inclinations. Still we drew nearer and closer—with wonderful displays of red rock disintegrating into rubble, and long sweeping and steep surfaces of comminuted stone. The higher cells, cirques or valleys in the mountains were floored with snow, and occasional glacial patches were uncertainly described. At a distance these mountains looked like a serrated range on a single base of extension, but nearer they were seen to be in ranks thrown up in most effective hummocky confusion.

And now a thousand lights play over them, and now they gleam with one consentaneous and single glory, like a pale and myriad faceted ruby. New features come into view on every side, at each new inclination of the ship; a rainbow stands upright piercing the zenith,



AKREYRI.

almost above them, and the sun floods the skies with pink and purple hues, painting also the low-lying bars of cloud with gold, to be itself slowly, slowly, quenched in a roseate ocean. And still the alpine glow bathed all the scene with opalescent reds, with violet colorings and russet lines, while the shadows of the higher peaks lay black upon the snows of the valleys below them. The picture remained perfect for an hour, its high lights shifting, but its beauty penetrating and immanent, spreading all over the solemn austere hills with changing marvelousness.

In the morning we found ourselves at the bottom of a fiord at the head of which we confronted an extensive marsh. This was Akreyri, a good-sized place, running around a curved shore with large frame houses, some three stories high, and a good road along the shore and up into the hills. About a quarter of a mile from the landing dock there is a deep *till* morainal deposit, packed with rounded pebbles, and prevalent evidence of an old beach line. Back of the shore on the village side rose sculptured snow mountains, and opposite across the fiord the long slant of a hill dissected by rill channels. This hill was the



ODDEYIL.

usual wall or palisade of lava flows, with green grassed slopes at its foot.

The town, containing about 3,000 people, consists of sizable frame houses, some quite large. The public school is commodious, and there is a hospital and a hotel. The streets are named and the houses numbered. Here trailing along the roadsides and dotting the fields in color patches were the wild pansies (*Viola tricolor*).

The next stop was in the Skagafjord at Saudarkrokr, where a remarkable raised beach suggested geological themes. If I was not mistaken in my notes on the conversation between a fisherman and the steward of our steamer, the fisherman was induced to furnish us with good herring at about a farthing a pound, which same fish sell for almost twelve cents a pound in Copenhagen. Fish were all about us and the herring nets, floated by buoys, seamed the water, with fishermen moving slowly to and fro gathering them in. The Iclander peasant fisherman is very poor, and, clad in rough clothes, with hairy bristling whiskers and worn eyes and shock hair, has sometimes quite an aboriginal appearance. He wears a sheep-skin slipper on his foot and heavy encasing woolen socks underneath leggings, and has no scruples about



RYKIAFIORD.

wading in the water as indifferently as if he wore Goodyear Rubber Company boots.

More geological themes stared us in the face at Blönduos where a glacial river discharges its mineral burdens into the sea in a turbid muddy tide. Again at Reykiarfiord we were called upon to esteem the endurance of the Icелander. The place is rough and stony, with a few houses and turf-covered cabins, an eider duck island or so, and wore an expression of depressing loneliness, albeit in the bright sunlight it bravely challenged our admiration. Again on our way with our former tireless companion—fog. In the weird night dawn, with the fog dissipated and the north cape passed, we pushed on to Isafjardarjup; and the high shores with dark menacing and austere contours loomed strangely over the fringed spray-scurried waves hissing around us. We plunged headlong into the inky billows until the cape headland gave us shelter, and the confusion about us subsided, and in the morning we woke in Isafjord—a thriving town on a crescentic spit of land enclosing a quiet lake-like harbor in which the *Vesta* floated.

This fiord was the usual thing; walled in by high cliffs, plainly



COD FLAKES IN THE VILLAGE OF ISAFJORD.

banded by the successive flows of igneous rock, while at one point on the east wall an amphitheatrical cup was seen, just such as prevailed elsewhere, but here somewhat larger and accessible, and which begins the degradation and removal of the basaltic cliffs.

Early in the morning we left the steamer for the shore, and traversed the town. We saw the big cod storehouses where perhaps \$10,000 worth of dried flat cod were piled up in snowy walls to the roof. Women work, spreading and weighing them, over the rocks. These women work eight or ten hours a day, and receive about fifty cents a day, the men about one dollar. The fish, headed and cleaned, of course, are gathered into flat piles over night, covered with oil skins, on which planks are placed, carrying a weight of stones, and distributed in the morning if the day is clear. There are perhaps three or four such establishments in the town, and they fill it with bustle and commercial activity. Stores (*Verzlun*), opened by German and Scotch traders, dispense to the people dry goods, art material, decorations and utensils, coffee houses entertain them, and, judging from the crowded



COD ON STONES, ISAFIORD.

post-office—to which our steamer had brought the letters—the outer world regularly reaches their doors.

I looked into the modest little church through its windows and discovered the altar with candles and a figure of the Christ. The religion of the island is Lutheran. The graves were marked in many instances by polished granite tombstones, many with Thorwaldsen's "Night," in a white medallion of porcelain, upon them, and all more or less covered with tin flowers and tin palms with linen flowers, in white, and many withered wreaths of bear-berries.

After breakfast I climbed up into the amphitheater on the palisades to the east, which in the shadows of the morning seemed remote and fascinating, with a great boulder of *liparite* flung upon its extremest lip like a propylon at the entrance of a temple. The views from this cup of erosion with its steep talus-slopes of comminuted stone—splinters and angular chips dislodged by frost, were superb—the outer fiord with its snow mountains with the water at their feet dyed *bleu foncée*, and the hill country southward with snow banks and threading



DYRIFJORD VILLAGE.

streams and Isafjord below me like a map. The outer entrance of the Isafjardarjup is magnificent and was seen about two o'clock in the morning, a bold, deeply fissured and mountainous coast.

Our next stop was Thingeyri, on the Dyrifjord, which was a small place in a rather deep fiord, the sides of the fiord displaying a series of radiating valleys divided from each other by eroded walls of rock, which presented sharp prow-like fronts on the fiord. The landscape here had a dusty, dry and barren expression with poverty of green surfaces, the rock gravelly and crumbling, and a hard strange loneliness enveloped everything. The long morainal wall at the mouth of the fiord has been dissected by elevation and the attacks of the sea, and continues the encircling chain of evidence around the shores of the island, of its elevation since glacial times, its emergence, which has brought in many places beds of marine shells into dry and exposed positions. To the south as we rolled again on the waters of the Denmark Strait, headland after headland succeeded each other down the coast with splendid sweeping beaches between. Then came a most remarkable long precipitous wall, like a creation of masonry, spattered



WEATHERED PALISADES IN DYRIFIORD.

fantastically with white splotches of guano, and celebrated as a home for the sea-birds, a veritable basaltic dike, eaten into by time and weathering, and furnishing innumerable nooks and ledges for the great population it harbored.

Desperate and vain efforts to get it to "go off" involved the captain and the engineer in savage denunciations of a small brass cannon, whose thunders were to awaken the sleeping (or dozing) inhabitants of this mural metropolis. When at last it sputtered its salute, a solitary bird rose jeeringly in the air, and the show was over.

Now we were crossing the Breitfiord (the broad fiord) a vast bay, sprinkled with stumps of rock in chains of islets, and darkening ominously under gathering wind-clouds, whose first puffs began to rumple and whiten the wide expanse. Then came a marine idyll, a little grass-covered island with rocky reefs and walls, and its upland quaintly decorated with a little village and small farm houses, whose roofs were white with flowering shepherd's purse and wild mustard, shooting up most naturally from the turf gables. The men and women were out harvesting the hay, and the pictorial charm of everything was

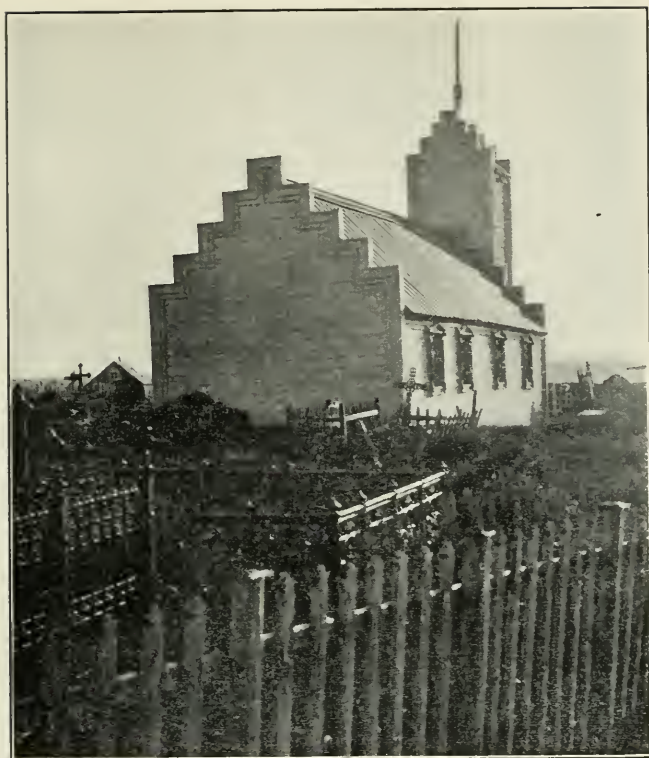


HOUSES AND SURF WALL AT FLATEY ISLAND, BREITFIORD.

increased by a slanting towered church very odd and lovely too, with its disheveled graveyard about it.

We crossed the bay to Stykkisholm, a picturesque village made up of snugly elbowing houses, crumpled together on a high rock, with black islets all about. It was ten o'clock p.m., and a yellow splendor filled the western sky, against whose wild light the sharply scissored outlines of the mountains ran in a black silhouette. The great arc-like boats came off in the morning from the shore, and were loaded, and their cargoes discharged on the dock, bands of women carrying the sacks on their backs, or taking the broad planks (for making furniture) between them.

We left Stykkisholm in the morning, which was cold and clear, and steamed out over the broad fiord with the snow mountains distantly gleaming and the lead-bottomed clouds in angry rolls pouring over them to the south. Towards three in the afternoon we reached the crater-peak of Snaefells, with its glacier or jokull, which terminates the long peninsula between the Breitfiord and the Faxafiord. At first Snaefells was clouded and capped with mists. Then we saw a long



LITTLE CHURCH ON FLATEY ISLAND, BREITFIORD.

flat flow of trap on the coast, spattered, like the bird-rock we had passed, with guano, and riddled with caves and excavations, and following that, we approached the shore at the base of the magnificent mountain. It was a beautiful picture, its expanded base rising into a dome on which spread the ice and snow cap-like flat helmet, surmounted by two monticules or mammillary peaks, one darkened by an enclosed rock. The view of the mountain improved each minute, until at last its glorious argent dome was swept clear of clouds, and in the lucid brilliant air shone like a silver shield. The physical aspects of the mountain below the snow fields were most interesting. The guttered flanks, deeply channeled with a network of *rainures*, whose interlaced troughs resembled the crossing and interference of paths of flowing material, but was interpreted by Professor Gourdon as purely erosive, were highly instructive. The spectacle the mountain made was undoubtedly very fine, and for the whole afternoon, until actual semi-night and knotted clouds hid it from sight, it remained the majestic crown to the broad panorama of snow mountains stretching eastward. We were now in the Faxafjord.



STYKKISHOLM.

And then came Reykjavik, of which and the *interior* of Iceland the editor may permit me to say something at another time.

NOTES ON THE DEVELOPMENT OF TELEPHONE SERVICE

BY FRED DELAND
PITTSBURGH, PA.

XVI. THE HARD TIMES OF 1885

THE year 1885 will never be forgotten by the "hard times" sufferers—nor by many operating telephone companies. For commercial and industrial conditions rapidly slid down to bedrock, and thousands who were thrown out of employment suffered for the bare necessities of life. Some of the local telephone companies had a fair income, but nearly all had to defend at heavy cost, a series of systematic attacks upon the rates charged for local service. In 1885 the bank clearances were over fifteen billions of dollars less than in 1883, the production of pig iron was lessened by nearly 600,000 tons, while its price fell to \$18 a ton from \$22 a ton in 1883. So great a commercial and industrial depression naturally affected the financial growth of the parent Bell company; and then, that its bitter cup might be full to overflowing, all the power of the United States government was brought to bear on the fundamental Bell patent, in the hope that it might be invalidated. Referring to this most unjust and discreditable attempt to lend the dignity and the power of the United States to a deliberate scheme to filch honors justly awarded, the editor of *The Nation* wrote that this

decision to have the validity of the Bell telephone patent tested in the courts . . . insures the success of one of the worst stock-jobbing schemes now before the public. The stock in trade of the companies on whose motion the suit is brought consists of a paper capital of several millions, and a few patents of insignificant value which they probably never intended to use.

In July commercial conditions in the east experienced a brief boom, brought about by the absorption of the costly West Shore line by the New York Central interests. But the farming community had invested heavily in West Shore, and following the reaction due to heavy losses distributed among a large number of grangers came increased distrust not only in railway, but in all industrial securities, including even those of the best local Bell companies.

However, the farmers were enriched by the greatest crop of corn ever grown up to that year, exceeding by one hundred and forty million bushels the bumper crop of the previous year, while the yield of cotton secured by planters in the south was nearly as large as the summer before. But the farmers harvested one hundred and fifty-five million

bushels less of wheat than in 1884, and a bushel of wheat was worth nearly two bushels of corn, wheat selling at an average export price of 87 cents and corn at 49 cents per bushel. On the Chicago market wheat ranged from $73\frac{3}{8}$ cents to $91\frac{3}{4}$ cents per bushel. During the fiscal year beginning July 1, 1885, there was exported only 57,759,209 bushels of wheat having an aggregate value of \$50,262,715, as against 106,385,828 bushels in 1882 having an aggregate value of \$119,879,341.

Each month brought reports of the large number of telephones taken out at the request of subscribers; yet, when the returns for the year were tabulated, the totals for all the Bell companies in the United States showed a net gain in subscribers of 2,903. Owing to the extreme financial depression this was an entirely unexpected increase.

One company, in reporting a gain for the year of nineteen stations, expressed its elation over the fact that it meant a net gain of thirty paying stations through the elimination of a number of deadheads. This company reported having "removed 1,147 instruments and placed 1,179," during 1885, and added:

When we analyze the places in which we gain and lose, we find that of the fourteen exchanges containing over one hundred subscribers, which we are working to-day, all but three are larger than they were a year ago, while of the nineteen exchanges of less than one hundred, all but six are smaller than they were in April, 1884.

This company was operating thirty-three exchanges with an average of 171 subscribers to each exchange, and was in a stronger financial condition than three fourths of the other companies. Yet its treasury stock was unsalable at any reasonable price, even though the purchaser knew that the entire proceeds of the sale would be devoted to new construction. Two and three years previously people went wild over telephone stocks, not only borrowing money from banks to use in purchasing telephone securities, but actually mortgaging homes. But during 1885, it was only possible to dispose of many local telephone stocks by allowing an enormous discount of from 50 to 80 per cent. from par value. So this company told its stockholders that

we are convinced that we are now at the period when we must look to our current earnings to pay for all expenditures of every kind whatsoever. The system, as now established, must not only maintain itself, but must provide for the ordinary extensions and improvements which the growth of population and business and the development of improved apparatus may demand.

Notwithstanding the several concessions granted its licensees by the parent company during the previous year, it perceived early in 1885, that the prevailing industrial conditions coupled with the low financial condition of a majority of the local companies, rendered necessary a further modification in relationship. During 1884 the parent company returned \$806,634 to the operating companies in which it held shares of stock, which was its proportion of the net earnings,

that this amount might be spent for necessary improvements and extensions on the part of the local companies.

Following many of the numerous consolidations, the parent company granted to the consolidated companies a perpetual license covering the exclusive use of Bell equipment in specified territory, in exchange for the short-term licenses that had expired or were about to expire. In return for these perpetual exclusive rights the local companies issued to the parent company from 20 to 33 per cent. of the capital stock of the new organizations. Thus parent and operating companies became joint partners having every reason to protect each other's interests, even after the expiration of the fundamental patents.

Owing to the stress of financial conditions, early in 1885, the parent company decided to call a conference of the operating companies to ascertain what mutual action was advisable, in order to restore confidence among the shareholders of the consolidated companies, as well as to awaken an interest in telephone securities on the part of prospective purchasers. With that end in view it invited all local companies to send one or more representatives to a meeting to be held in Boston, June 8 to 13.

During the sessions of this conference all phases of relationship were broadly discussed and many perplexing problems thoroughly threshed out, several important concessions were made, and a further reduction in royalties announced. At the closing session the delegates tendered to the parent company a vote of thanks

for the substantial benefits resulting from the conference and its disposition to strengthen our hands in developing the business; (and assured) a continuance of our hearty support and cooperation, with renewed vigor and confidence.

In its annual report for 1885, the parent company referred to the results of this conference as follows:

With longer experience the telephone companies have learned that the cost of maintaining and reconstructing their plant has been generally underestimated, and many of them have in consequence been forced to recognize that the profits upon telephone business are less than they had expected and believed. For this reason they have appealed to us to make certain concessions in their contract relations, and we have given this subject careful consideration. . . . We have met our licensees; *first*, by agreeing when desired, that our share of net earnings, jointly with theirs, may be used for construction purposes, so that we in these cases are sharing the cost of developing the business; *second*, we have made a reduction in the royalties on telephones used in small places where the rates are low. This reduction involves a loss of royalty amounting to about \$200,000 per annum on our present business.

While comparisons are rarely pleasant to present, yet it is interesting to compare this voluntary action on the part of the Bell company, with the resolutions passed by the licensees of another parent public utility company. This latter parent company was not in the telephone business, but it made arrangements

by which these local companies had the exclusive and absolute right to the sale of apparatus in their respective territories. In return for this they gave to the company a certain percentage of their capital stock, not for one year or two

years, or any fixed length of time, but perpetually and upon any increase of capital stock. These licensees, however, were not guaranteed by the parent company against infringers of the patents, or given protection in any way equal at the time to the rights which they sacrificed. The makers of other apparatus which infringed the patent came into their territory unmolested and sold in competition with them. The result is that during the past ten years the licensees have not secured any considerable portion of the profits which justly belong to them. In return for the stock which they surrendered the local companies were to secure a special rate upon apparatus, which would enable them to compete successfully with any rivals. As a matter of fact this privilege was never secured and the apparatus of other manufacturers could be obtained upon the market at a price which was actually less than that which they had to pay to the parent company.

During the year 1885 systematic attacks upon the rates charged by operating Bell companies were started in several states, notably in Massachusetts and in Indiana. In Massachusetts the movement began the previous year, and is said to have been instigated by and supported almost entirely through the efforts of one man who felt that he had not been fairly treated by his associates when the local company in which he was a shareholder had been absorbed in a general consolidation. The method this man adopted was to employ boys in different cities to rapidly circulate petitions in favor of reducing telephone rates in the respective localities. Naturally, not only friends and acquaintances of the boys, but thousands of other persons signed the petitions to help the lads earn the promised pennies. In this manner a total of about 50,000 signatures were secured. When these petitions were presented to the legislature, it was shown that nearly three fourths of the signers were not subscribers to telephone service, that a number of names had been placed on the petitions without authority, and that many of the alleged petitioners could not be located. For instance, ninety signatures were secured in Lynn, and only four of the entire number represented telephone subscribers. Of the eighty-six non-subscribers, the names of twenty-seven did not appear in the city directory, nor could the individuals be found. Then it was publicly charged that this lot of petitions had been shown to the Bell interests and offered to them for \$12,000 in cash. It was further stated that

as no purchaser could be found, the whole batch of petitions finally found their way to the legislature, which, in its final judgment, placed the same value upon them as the directors of the Bell company had previously done.

On April 13, 1885, the Indiana legislature passed a drastic law that later was repealed:

that no individual, company or corporation now or hereafter owning, controlling or operating any telephone line in operation in this State shall be allowed to charge, collect or receive as rental for the use of such telephones a sum exceeding three dollars per month where one telephone only is rented by one individual, company or corporation. Where two or more telephones are rented by the same individual, company or corporation, the rental per month for each telephone so rented shall not exceed two dollars and fifty cents per month.

When this law went into effect, six different companies or individuals were operating telephone exchanges in Indiana under Bell licenses,

and as this bill threatened to largely reduce their prospective incomes, it required wise planning to keep the outgo within the estimated income in order to avoid bankruptcy. The first step taken was to suspend night service in some places. In turn the citizens, the great majority of whom had never patronized the telephone company, exhibited an utter disregard for the rights of others by cutting down the telephone poles. A large number of exchanges and over one hundred toll stations in Indiana were closed, and all improvements and extensions ceased.

Fortunately for all concerned, there was a golden lining to the dark cloud that overhung the telephone field in 1885, in this that no less than six important decisions were rendered in favor of Bell interests. Five of these were judicial, being handed down in the United States circuit courts in the respective districts, and one was the important decision rendered by Commissioner Butterworth of the Patent Office.

It may be recalled that on October 23, 1884, the examiners-in-chief in the United States Patent Office, after a very thorough and complete investigation of certain interference claims involving the invention of the telephone, and after each claimant had had his rights fully presented in lengthy arguments, decided that

Bell is the only one of the contestants having patents. Bell is not only a patentee, but it is to him that the world owes the possession of the speaking telephone.

Earlier in 1884 the examiner of interferences had rendered a similar decision, after eighteen months of thorough investigation. This decision was exceedingly elaborate, making a printed volume of over three hundred pages, and reviewing the law and the evidence, including every fact and phase with great care. From this decision the claimants appealed to the examiners-in-chief, as stated, and from their decision to the commissioner of patents. After a seven days hearing the commissioner decided that

Bell discovered, and his patent showed that a certain combination of magnet, diaphragm and armature, when arranged in a specified connection with other specified parts, constituted an apparatus which would transmit articulate speech. Up to this time no one else had done this, or had known it. The combination was the result of his conception and the outgrowth of his theory, and the apparatus, being a materialization of that conception and in conformity to that theory, was his original invention.

In January, 1885, Judge Butler, in the United States Circuit Court, District of Pennsylvania, in granting the motion of the parent Bell company for an injunction, decided that

upon full and patient examination of everything submitted to us, we believe that the alleged new matter is but the refuse and dregs of the former cases—if I might be allowed the use of so homely an illustration, I would say, but the heel taps found in the glasses at the end of the frolic.

In March, 1885, Judge Wallace, in the United States Circuit Court, Northern District of New York, in granting the request for an injunc-

tion against an infringing company, stated that

this is a case in which an injunction must issue, beyond any sort of doubt. The questions upon the merits, for the purpose of preliminary injunction, have been already disposed of in the Pennsylvania and New Jersey cases,

In June, 1885, Judge Wallace, in deciding that the Molecular Company had infringed "all the claims" of the Bell patent, stated:

After Bell has pointed out the way, it may now be seen to be a simple thing to introduce his method into the Reis apparatus. Some of the experts have doubtless convinced themselves that these modifications of the Reis apparatus do not involve any difference in the principle of the apparatus. It is too late to accept this theory after the lapse of so many years of fruitless experiment with the method of Reis, as originally suggested by Bourseul, and with the apparatus of Reis, as modified by various experimentalists down to the time of the promulgation of Bell's method. It seems impossible to escape the conviction that had the speaking telephone been left where it was left by Reis, and by those who endeavored to develop and perfect his theory, it would only have realized the speculations of Bourseul.

In July, 1885, Judges McKennan and Acheson, in the Circuit Court of the United States, Western District of Pennsylvania, in allowing an injunction stated

that while this country has been agitated for several years past by litigation about this Bell telephone, and while there were decisions in the courts, at any rate in Massachusetts and in New York, and in this circuit, these defendants, with the knowledge of all these decisions, have entered upon a course of infringement of the rights of these complainants, that have been passed upon by the courts. . . . If these people, believing that they had a right to do it, without any decision of the Court, and without any notice whatever from the party whose rights they sought to appropriate, had commenced this business, it might be said with some sort of claim of equity, that they had been misled, and that therefore, they ought not to be stopped by an injunction where such injunctions would subject them to loss which they did not expect. That is not the case here as I have said several times. They have invited this controversy. They have stood up and said to Bell, "You are not the inventor of this thing, and we are going on in defiance of the patent which has been granted by the Government, and in defiance of the decisions of the Courts sustaining it." Now, that is just the aspect of the case, and I know of no rule by which the Court has heretofore been governed in the disposition of motions of this kind, which would justify us, for one moment, in treating these defendants with special favor, even independent of the decisions of the Circuit Courts. The injunction is allowed.

In December, 1885, Judge Wallace said:

Since the decision of this case in December last, additional proofs have been taken on the part of the defendants (The People's Telephone Co.) and by consent of complainants, have been presented for the further consideration of the Court after argument of counsel. All the new evidence is cumulative merely. Such as consists of the testimony of new witnesses to knowledge of the existence of Drawbaugh's talking machine prior to the date of the Bell patent, is far less persuasive than much which has already been considered and rejected as incredible. . . . The legitimate effect of the evidence is to show that Drawbaugh was very near the realization of the invention, if he had really constructed instruments like the exhibits *F*, *B* and *C*, prior to the date of Bell's patent. It does not, however, alter the fact that he was unable to make such instruments at a period long subsequent to the time when he claims to have made them; and in view of this fact the evidence does not tend to materially fortify the testimony of the witnesses, who think, or profess to think, that they heard, or saw efficient practical instruments in operation at Drawbaugh's shop on the occasions to which they refer. The conclusions which were reached at the former hearing have not been modified and the decree ordered should not be disturbed.

THE INSTITUTE OF FRANCE, AND SOME LEARNED SOCIETIES OF PARIS¹

BY EDWARD F. WILLIAMS

CHICAGO

I

THE Institute of France has been called the greatest educational work any government has ever organized and supported. Be that as it may, there is no denying that the service it has rendered learning and literature, scientific research and the fine arts, has been extensive and stimulating, that, beginning with the organization of the French Academy in the time of Richelieu, its history covers in a good degree the history of the intellectual and social development of the French people.

The institute embraces in its present organization five academies which in the order of their establishment, if not in importance, are as follows: The French Academy, to which the forty immortals belong, the Academy of Inscriptions and Belles-lettres, the Academy of Sciences, the Academy of Fine Arts, the Academy of Moral and Political Science. The academies existing at the time of the revolution were abolished by the Convention as aristocratic in their tendency, and some of their members, known or supposed to be in favor of the monarchy, were guillotined, but as it was soon discovered that the knowledge of the members of the Academy of Sciences could be made of use to the new government, they were appointed on the commission of weights and measures. Thus some of the members of the old organization, meeting occasionally for the discussion of scientific subjects, managed to preserve at least the semblance of an academy of science. The so-called National Institute of Science and the Arts was recognized by the Directory August 22, 1795, and divided into three classes: (1) physical science and mathematics, (2) moral and political science, (3) literature and fine arts. From about 1667 to 1806 the sessions of the academies were held in the Louvre, in the great hall of Henry II. Since that time they have been held in a building which belongs to the institute, the Mazarin Palace, which was built by Cardinal Mazarin for the College of the Four Nations during the years 1661-5. It contains his library of more than 100,000 volumes, which is cared for

¹ Authorities: Maury, 'History of the Old Academy of Science'; reports of the academy from year to year; statements in Minerva from its foundation; 'History of Paris Educational Institutions,' by Alexandre De Maistre.

by a member of the institute. The institute has its own library also, equally large and embracing nearly all the books which are of interest to its members. The five academies are thus housed under one roof and on different days occupy for their gatherings the same rooms. To the public only the halls are open in which the annual meetings or receptions are held, though far more important for the members of the institute are the laboratories, or the rooms in which they do their work. While each academy is independent, there is yet a government common to the five academies in addition to the supervision exercised over them by the minister of public instruction. The institute has had no political power, and care has been taken to reduce its possible political influence to the lowest terms. So great was the fear of this influence that parliament in the time of Richelieu hesitated for more than two years before granting the original academy a charter. It was this same fear which led the convention to abolish the academies altogether. The history of the last hundred years shows how groundless these fears were, and how wise it is to favor organizations of learned men for the cultivation of whatever fields of literature or science they choose to enter.

The institute was reorganized by Napoleon in 1803 as the Imperial Institute of France, and divided into four classes: (1) Mathematics and natural science, (2) French language and literature, (3) classical languages and literature, (4) fine arts. After the restoration in 1816 the institute was again reorganized as the Institute of France and to it in 1832 a fifth academy was added, that of moral and political science. Each of these academies, or classes, elects its own members, subject to the approval of the government, but are all controlled by a committee representing each one of them.

The French Academy

The oldest of these academies (l'Académie française), the French Academy, was founded by Cardinal Richelieu in 1634. It received at Richelieu's request letters of recognition from Louis XIII. in January, 1635, but was not recognized by parliament till July 10, 1637. As early as 1630 a number of literary men had met at each others houses to discuss subjects of a literary nature and to encourage each other in efforts to improve the language and literature of the nation. Richelieu, then prime minister, determined to give the association his favor and to bring it into connection with the government. As a government institution he believed it would reflect credit upon the reign of the sovereign. For a few years the meetings were held in the Royal Library. Its purpose was declared to be, to improve the French language, criticize literary works and make a dictionary. Richelieu was anxious that it should publish a grammar also, a rhetoric, and an

authoritative treatise on poetry, but for some reason his wish has not yet been realized.

Membership in the academy was made difficult from the first. A few men, Boisrobert, Conrart, Chapelaine, Rotrau and Corneille were enrolled as a matter of course, as charter members. But only the most eminent literary men were to wear its honors. Two years after its recognition by parliament the number of its members was fixed at forty, and this number has remained unchanged till now. The privilege of being one of the forty must be sought for, and the person desiring election must personally visit each one of the members and solicit his vote. In the case of Buffon, Thiers and Béranger the rule was set aside, but as Béranger declined the offered honor, the rule of personal solicitation has become more rigid than ever.

The reception of a new member is public and is a great occasion. The new member is expected to eulogize the man whose place he has been chosen to fill, and to give in writing an estimate of the value of his works. To his thanks for the honor he has received through his reception into the academy the president responds in a few fitting words. The public, sometimes dissatisfied with the action of the academy, has created a *forty-first chair*, into which it puts the man who has been overlooked or neglected. In this chair it has seated Descartes, Pascal, Molière, Rousseau, Diderot, Dumas père, Balzac, Alphonse Daudet, Emile Zola. In 1778 the bust of Molière was set up in the hall with the inscription:

Rien ne manque à sa gloire, il manquait à la nôtre.

Though by no means a bureau of lexicography, its chief work, outside of criticism, has been the making of a dictionary of which the first edition, after fifty-nine years of labor, appeared in 1694, the eighth in 1896. Colbert when prime minister is reported to have been very impatient over the progress the dictionary was making, and one day, quite unexpectedly, came upon the academicians when at their work. Listening for a time to the definitions proposed for a very simple word, to the discussions which followed, and perceiving the difficulties in securing a definition at once comprehensive and accurate, he concluded that the task in hand would require far more time than he had thought, and was indeed a far more difficult task than he had supposed. From this time on he ceased his criticisms. The academy is now planning and at work on a historical dictionary of the language, on a scale so large that a wag has said it will take at least a thousand years to complete it, but he adds, as it is made up of *immortals*, the element of time need not be considered.

The academy expends more than 100,000 francs a year (\$20,000) in prizes. These are granted for the best work in poetry, history or

moral philosophy which has appeared during the year, and also for the best oration or essay. The Montyon prizes, worth 22,463 francs, are for the best work of any sort by a Frenchman produced during the preceding twelve months. A prize, worth 21,940 francs, is for the best work on the application of knowledge to the arts. The Gobert prizes are for the best history of France, or on some point connected with its history. A special prize is offered every year for the best poem or essay upon a subject which the academy itself suggests.

The government pays each of the members of the academy the sum of 1,200 francs a year as a pension. The same sum is given to the members of the other academies which belong to the institute. The secretaries of the different academies receive 6,000 francs annually. Special grants are made from time to time for special objects. Thus in 1902, 10,300 francs were voted for the dictionary and other publications, 4,000 francs for a special prize, and 13,900 francs for miscellaneous uses. Sessions are private, save at the reception of a new member, the annual meeting in November, and the gathering of all the academies on October 25, when the large hall is crowded to suffocation.

It is impossible to estimate the influence which this academy has exerted on the literary life and taste of the French people. Nor can one determine the value of its contributions to the development and purification of the French language. There can be no doubt of its usefulness, or that in its work it has more than realized the hopes of its founders. Its influence at present is hardly less powerful than in the earlier years of its life. In fact, it may be truthfully said that in its unique character and position it has long been, and still is, the wonder and despair of other nations.

The Academy of Inscriptions and Belles-lettres

This academy, the 'little academy,' as it was nicknamed, the second in the order of formation, was established under the ministry of Colbert in 1665. At first it was simply a committee of four persons chosen from the French academy to work on inscriptions, form devices or emblems, suggest medals representing important and striking facts in the national history and furnish designs for the royal tapestry. It did not receive its name or enter upon its definite field of labor till 1701. Prior to this time its members, whose number had been gradually increased, discussed antiquarian and archeological subjects, and in this direction did good work. It was in the year 1701 that the Abbé Bignon asked the king to recognize it as an academy, give it a name and determine its duties.

Although the request of the abbé was received favorably, the new academy did not receive its charter till the time of Ponchartrain, July 16, 1706. Its name or title was not given till 1716. Then, as now, it

had forty working members resident in Paris. There were ten associate or free members, in training for vacancies in the active membership. There were eight foreign associate members and fifty corresponding members. This academy was suppressed by the Convention in 1793 and did not reopen under the Directory in 1795.

It was reconstructed by Napoleon in 1803 under the title of 1716, and its old field, the study of language, assigned to it. It now gives, through carefully selected committees, special attention to the study of Greek and Roman antiquities, as well as to those connected with French history, to Assyriology, Egyptology, epigraphy and the literary history of France. It looks after the French schools in Rome and Athens, which under its guidance have made important antiquarian researches and discoveries in Greece, the Grecian islands, Italy, Asia Minor, North Africa and Syria. Its *Mémoires* are full of extremely valuable information. Its activity along its various lines of study and research is unabated, and the means for the enlargement of its work, in addition to government support, are constantly increasing.

It grants several prizes, but no one of them is so highly esteemed and so eagerly sought for as the one which secures its holder two years' residence and study in Rome and Athens. The prize is won in a severe examination and against many competitors. It was through the influence of members of the school at Athens, and under their personal direction, that the temple at Delphi was uncovered, and that many other interesting remains of Grecian antiquity have been brought to light. To no one of the academies connected with the institute are students of history, the classics, antiquities of every sort and oriental languages, more deeply indebted than to the academy of inscriptions. Some of its members have been among the leading scholars of the nineteenth century. Its standard of work is very high, as one who will read the jubilee history of the school in Athens will discover. Nor is its work of less interest or importance to-day than it has been in the past. While granting prizes every year there is one prize, the Louis Fould, worth 20,000 francs, which prior to 1896 had never been awarded. It is offered once in three years for a satisfactory history of the arts of design, their origin and progress, and their transmission through different peoples to the time of Pericles. The subject is so difficult and the scholarship required so extensive and accurate that few can hope to win it.

The Academy of Sciences

The Academy of Sciences, regarded by scientific men as the most important part of the institute, and whose history will be related more fully in other articles, was founded by Minister Colbert in 1666. It grew out of informal gatherings of scientific men who met from time

to time to discuss reported discoveries in the scientific world and to suggest and criticize theories of their own. It is the largest of all the academies connected with the institute, having sixty-eight members, two secretaries, ten free members in training for vacancies in the active membership, ten honorary members residing in France, eight foreign associates and one hundred corresponding members. It receives an annual grant of 64,000 francs for publications and has a large amount of money at its disposal for prizes. The work of the academy, which is very extensive and which aims to cover the whole scientific field, is done through committees. In the mathematical section of the academy there are committees for geometry, mechanics, astronomy, geography and ship building. In the section devoted to physics there are committees for chemistry, mineralogy, botany, rural economy, anatomy, zoology, medicine and surgery. The sessions are on Mondays at 3 P.M., although the members of the academy are in their laboratories every day in the week with the exception of Sunday. Its work in science has perhaps been more brilliant and extensive than that of any other scientific academy in the world. It offers an annual prize of 3,000 francs for the best discussion which has appeared during the year on a mathematical topic or on one in physics. It has six Montyon prizes at its disposal, worth in all 44,845 francs. The valuable Laland prize for astronomical work is under its control. Its annual meeting is in December. Its Mémoires are of the greatest value, and are highly prized by scientific students the world over. From property made over to it by the Duc d'Aumale in 1886, at Chantilly, it is thought an income of at least 550,000 francs each year will be received. This income is not yet fully available.

The Academy of Fine Arts

The Academy of Fine Arts, though existing under this name only since 1795, was really founded by Mazarin in 1648 as an academy of painting. Sculpture was made one of its departments in 1664, music another in 1668, architecture another in 1671. In 1815 this academy was fourth in order of importance in the institute and in order of organization. At that time some of the first men in France were members of it. Its chief interest is, and has been, in and for the fine arts. In this department of study it has been preeminent. Although its publication fund has been only 6,000 francs a year, it has brought out many valuable works, among them a dictionary of the fine arts. It has forty members, ten associate members in training for the vacancies which may occur, ten foreign associate and sixty-one corresponding members. Its annual meeting is one of the great social events of the year. It takes place in October. Women are always present in large numbers. While the addresses are interesting, the chief attractions are

in the distributing of the prizes, which consist of a medal and a diploma which entitle the possessor to a two years' residence in Rome. These prizes are granted for excellence in painting, sculpture, architecture and musical composition. Its meetings, like those of the Academy of the Immortals, are in private, while those of the other academies, though attended by but few, are open to the public.

The Academy of Moral and Political Science

The Academy of Moral and Political Science was the creation of the revolution. By its originators it was made the fourth in the institute. Suppressed by Napoleon in 1803, it was reestablished in 1832 at the suggestion of Guizot, then prime minister. It began with thirty members, but in 1855 the number was increased to forty, with ten free members in training for the vacancies, forty-five corresponding members and six foreign associate members. The academy does its work through five groups of men who form committees on philosophy, morals, legislation, public law and jurisprudence, political science and statistics, general and philosophical history. Its sessions are on Saturdays at 1 P.M. The academy has always been an object of dread to revolutionists, and to men like the first Napoleon, but of special interest to lovers of freedom and progress. Some of the most distinguished names in French history are on its books, names of men like Bartholomew St. Hilaire, who was an active member more than fifty years, Guizot, Louis Reybard, Jules Simon, Cousin, Geraud, Hippolyte Passy, Michelet and scores of others almost as eminent.

Other Learned Societies

But the institute, far-reaching as have been its aims, has by no means met all the needs of the learned men of Paris or prevented them from forming self-supporting societies in large numbers for special work in various fields of research. It has, in fact, stimulated the formation of these societies. The names of some of the more important of these societies follow:

The Academy of Medicine, formed by royal command December 10, 1820, has a constitution like that of the Academy of Sciences and a large membership. Its meetings are on Wednesdays during the working portion of the year.

The French Association for the Advancement of Science, now united with the Scientific Association of France, was founded by Le Verrier in 1864 and has at least 3,400 members, each one of whom pays as dues 20 francs a year.

The National Acclimatizing Society of France, zoology and botany applied, founded in 1854, has a membership of 1,000. The dues are 25 francs a year.

The Astronomical Society, founded 1803, has 500 members. Its dues for Frenchmen are 9 francs, for foreigners 12 francs.

The Anthropological Society: founded 1859; 500 members; dues 30 francs.

The National Society of French Antiquarians: founded 1805. Till 1813 The Celtic Academy.

The Asiatic Society: founded 1822; 250 members; dues 50 francs.

The Biological Society: formed 1848; 40 members, 22 associate and 15 corresponding members; dues for active members 20 francs, for associate 15 francs.

The Botanical Society of France: formed 1854; 360 members; dues 30 francs.

The Society of the National School of Maps: formed 1839; 346 members; dues 10 francs.

The Chemical Society: formed 1857; 1,500 members; dues for Frenchmen 36 francs; foreigners 25 francs.

The National Society of Surgery: formed 1843; 35 members; dues 60 francs. This society is formed of the most eminent surgeons, and is therefore limited in its membership.

The International Society of Electricians: formed 1883; 1,270 members; dues 20 francs.

The Entomological Society of France: formed 1832; 490 members; dues 25 francs.

The Geographical Society: formed 1821; 2,078 members; dues 36 francs.

The Geological Society of France: formed 1830; 30 members.

The Association for the Encouragement of Grecian Studies in France: formed 1867.

The Society of French History: formed 1833; 600 members; dues 30 francs.

The Society of Diplomatic History: formed 1886; 600 members; dues 20 francs.

The Paris Society of Linguistics: formed 1864; 228 members; dues 20 francs.

The Mathematical Society of France: formed 1872; 280 members; dues 20 francs.

The Paris Society of Medicine: formed 1796; 70 regular members; 15 honorary; associates unlimited; dues for regular members 30 francs.

The Meteorological Society of France: formed 1852; 145 members; dues 10 francs.

The French Society of Mineralogy: formed 1878; 200 members; dues 20 francs.

The French Society for Numismatics: formed 1865; 200 members; dues 30 francs; receives associate members whose dues are only 20 francs.

The French Society for Physics: formed 1873; entrance fee 10 francs; dues 20 francs, half as much for non-resident members.

The Society of Ancient French Texts: formed 1875; 350 members; entrance fee 10 francs; dues 25 francs.

The Zoological Society of France: formed 1876; 350 members; dues 20 francs.

Societies for the study of electricity, architecture, political and social science are filling an important place in the higher life of the city.

Observing the dates of the formation of these societies, one will perceive that nearly all of them came into existence during the nineteenth century, most of them in the first half of the century. By these dates one can trace with a good degree of accuracy the progress of science, and especially of that branch of science which each society represents. Other societies will of course be formed as the *call* for them *arises*. In many respects better work is done in these independent bodies than in the academies connected with the institute, which in part at least are under the control of the government, and in which membership is limited to those who have already won fame.

RECENT VIEWS AS TO THE ORIGIN OF THE GREEK
TEMPLE

BY DR. ALEXANDER F. CHAMBERLAIN

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GREEK genius was brought a little nearer that of the commonalty of mankind, some years ago, by the discovery that marble statues were painted red in imitation of the wooden human figures long after marble had come into use as a material for sculpture. It now seems as if the Greek temple was to be recognized as the imitation of something previously existing, and that once again the "gulf" over which the Greek mind is supposed to have suddenly leaped has been reduced to quite ordinary human dimensions. It has long been customary to look upon the Greek temple as absolutely unique; the Doric temple, even if it was suggested by the rock-hewn tombs of Beni-Hassan in Upper Egypt, being, after all, unlike anything else in the world. But the numerous archeological investigations of the last few years have resulted in making it certain that many ideas, formerly conceived of as strictly Hellenic or Egyptian, were rather Mediterranean or even European. And it is fair to argue that the Greek temple had behind it something that was not necessarily characteristic of the ancient Nile or Ægean alone. The more we know about the prehistoric Mediterranean area, the less are we inclined to attribute to one race or to one people the chief contributions to human civilization arising within its bounds.

In 1905, in an article in *Globus*, the German geographical and ethnological journal, Professor K. Fuchs put forward the theory that "the wooden prototype of the Greek temple was an *Almenhaus*, the house of a rich cattle-breeder of the central European plateau, whom a long winter compelled to lay in great stores of hay and forced to erect over the stable a large hay-loft which kept it warm." To central Europe belonged in ancient times a house which was, "at the same time the primitive form of the modern Czik wood-houses, the ancient Greek temple, and several modern Alpine types of dwellings." Beginning with the gable, Professor Fuchs derives each prominent part of the Greek temple from corresponding portions of the prehistoric central European cattle-breeder's house, and really advances some very good arguments, as the illustrations to the article indicate, for the opinion held by him. Even the columns find their place in this explanation, but not so satisfactorily as in the later theory of Sarasin. That the Greek temple had a wooden prototype is now beyond doubt, but it is by

no means certain that its ancestor was the cattle-house of the natives of prehistoric central Europe, whatever their racial affinities were. Nevertheless, there are remarkable analogies between the prehistoric "winged house" and the ancient Greek peripteros. Fuchs's theory, however, is rather "local," and therefore not so widely applicable as that of Sarasin.

Dr. Paul Sarasin, who, with his cousin Fritz, is well known for notable researches among the primitive peoples of Ceylon, Celebes, etc., propounded before the Berlin Anthropological Society in 1906 a new and attractive theory of the origin of the Doric temple, viz., from the "lake-dwelling," or "pile-dwelling," characteristic of certain regions of the ancient and the modern world. His essay, with numerous illustrations, has since been published in the *Zeitschrift für Ethnologie*. It deserves the careful perusal of every student of the history of art and architecture, for his intimate knowledge of the "pile-dwelling," particularly in Celebes, enables Dr. Sarasin to go into very interesting details in this matter, and to set forth his arguments in a most striking manner, enforced by the illustrations, which are very much to the point, and also somewhat convincing. According to Sarasin, the Greek temple with columns "is a highly idealized and conventionalized expression of the original pile-dwelling"—the columns are the piles, the ornamented superstructure the dwelling fixed upon them, the triglyphs the window-strips, the metope the partition, etc. In order to fully appreciate the merits of Sarasin's theory one must bring up before the mind the wooden forerunner of the Doric peripteros: "The columns were wooden pillars, the architraves wooden beams, the triglyphs wooden strips, the metopes boards with carved ornament; the wooden roof was covered with mud-thatch, and the wooden ridge ended in a bird made of cut boards (the acroterion)." Reducing the height of the columns a little, and increasing somewhat that of the superstructure, one has a building strikingly similar to (in many respects identical with) the pile-dwelling. The figures of the temple of Poseidon at Paestum and a pile-dwelling in Central Celebes show this very clearly. And it should be said that the pile-dwellings of Indonesia, occurring on land as well as in water, represent better a "pile-dwelling period," than the "reconstructed" lake-dwellings of Switzerland. During the later stone age and the bronze age, Dr. Sarasin thinks, moreover, pile-dwellings of a sort comparable with those to be met with in Celebes, were found over a considerable portion of Europe, not merely in lakes, rivers, etc., but also in swamps, and on the dry land. Such a one was, apparently the pile-dwelling of the Wauwyl bog investigated in 1904, and closely resembling the Celebean pile-dwelling of the marshy Lake Limbotto. In all probability there existed commonly in Europe to the end of the bronze age, and sporadically (in

Hungary, for example) much later, pile-dwellings of the kind in question. In Greece and many other parts of the then known world, the original human dwelling was the house on piles, which, therefore, was also the first dwelling of the gods and the first temple—the orthodox temple, as Sarasin phrases it—was a pile-dwelling. In very ingenious fashion Sarasin shows how the peculiarities of the various portions of the Greek temple can be developed from the pile-dwelling. The *megaron*, too, finds an analogue in the *lobo*, or “men’s house” of Malaysia.

The simplest form of the column is, of course, the pile driven into the pillar or resting upon it; the basis of the Ionic and Corinthian columns is to be seen in the stones placed under the piles to prevent too early decay, etc. The so-called *echinus*, the lower, round portion of the capital of the Doric column, corresponds to the round disc of stone or wood placed on top of the piles as a protection against rats, etc. The *abacus* has also its prototype in the pile-dwelling in the rest-piece for the beams, which is placed on the middle of the disc just described. The so-called proto-Doric columns of Egypt, which lack the *echinus*, go back, Sarasin suggests, to a pile-dwelling without such protective discs. The perpendicularity of the columns of the Ionic and Corinthian temples, as well as the slight upper inclination of the Doric, comes naturally enough from the conditions of the wooden piles and their arrangement. So also square columns and even fluting. The so-called *adricula*, according to Sarasin, is derived, not from the tent, as some have supposed, but from the small shade-roof seen in front of many Celebean pile-dwellings, under which the occupants sit protected from sun and rain. The “wall-temples” and the *cellæ* are easily developed from the open space under the dwelling in the pile-houses by building in between the columns—the prototypes are seen in the Celebean houses. The transformation of the upper part of the pile-dwelling, when no longer used for habitation, into the superstructure of the Greek temple with its ornamentation (the frieze has its forerunner in the pile-dwelling’s wooden carvings, etc.) was easily possible with an artistically-minded people. The substitution of stone for wood, Dr. Sarasin thinks, may have been an Egyptian invention.

If the present writer may be permitted to add to the ideas set forth by Dr. Sarasin, he would like to suggest the possibility of the existence of pile-dwellings in caves (such have been reported from prehistoric Sicily) having had something to do with the development of the original wooden pile-dwelling into the stone temple.

The theory of Sarasin has the advantage of proposing as the original prototype of the Greek temple something that was more or less cosmopolitan, a building that was common and natural over a large portion of the prehistoric world, and not some merely “local” model.

As Dr. Sarasin points out, the pile-dwelling served also as prototype of the Chinese and Japanese temples (in this case, since they are mostly constructed of wood the likeness is even more striking); likewise in Farther India, Hindustan, Arabia, Asia Minor, Egypt, etc., and even in prehistoric America. Moreover, not merely the "long temple," but the "round temple," goes back to the pile-house, as may be seen from the round pile-dwellings ascribed to the land of Punt, in Egyptian pictures dating from ca. 1500 B.C., which are practically identical in shape, etc., with pile-dwellings still to be seen in the Nicobar Islands and in certain parts of Africa.

Taken altogether, Sarasin's essay is one of the most interesting and suggestive contributions to the literature of the evolution of architecture that has appeared in a generation, and it illustrates the way in which the anthropological investigator can assist in the solution of many puzzling problems, which meet with no successful interpretation at the hands of the closet-student or the biased classicist. Dr. Sarasin has given but another proof of the fact that the highest genius of the ancient Greeks lay not in inventing great or beautiful things out-of-hand, but in idealizing, beautifying and harmonizing what had already long existed in common and wide-spread forms and fashions. And to that great art no human race is utterly a stranger; and many of them are much nearer the Greeks than most of us believe.

FERTILITY AND GENIUS

BY CHARLES KASSEL

FORT WORTH, TEXAS

MR. ROOSEVELT'S measuring of swords with the followers of Malthus has been so much used as a butt for mere jest that it seems difficult to approach the subject in a serious mood. To the thoughtful mind, none the less, the question is one of absorbing interest. With the economic phase of the problem, we are all, of course, familiar—the least informed needs no one to tell him that the more numerous the offspring the severer the strain upon the material resources of the family. It is with the psychological side of the matter that our chief interest is bound up. Does a large progeny mean a heightening or weakening of intellectual force in the offspring? Does it imply characteristics of temperament and disposition which we need not look for in the scions of smaller families? Upon this subject we are without data save such as are afforded by the pages of biography; but if the facts we gather from the lives in our libraries are a safe guide to a conclusion upon this question our worthy executive may well congratulate himself upon his insight and philosophic wisdom.

We have examined some hundred or more biographies of noted characters—the most eminent, as we deemed, of those whose lives were accessible—and, of these, seventy-six mentioned the number of children making up the family of which the personage treated was a member. The data thus obtained we have tabulated in order, with the following result:

Horace Walpole—historic in English annals for political astuteness—was one of nineteen children.

Benjamin Franklin was one of seventeen children.

John Marshall—that greatest of American jurists—was one of fifteen children.

Peter the Great—the monarch to whom Russia is in great part indebted for what she is to-day—was one of fourteen children.

Napoleon Bonaparte—one of the most colossal figures in history—was one of thirteen children, as was also Samuel Taylor Coleridge, the English poet.

Samuel Adams, the American patriot and statesman; Sir Walter Scott, the English poet and novelist; the American writer James Fenimore Cooper, and, last, but greatest of all, Alfred Tennyson—that

minstrel of a many chorded harp—belonged to families of twelve children.

Lord Nelson, the English admiral; Washington Irving, the American essayist, and James Buchanan, aforetime president of the United States, were members of families of eleven children.

The number ten, perhaps, enjoys a prouder boast than any other, for among those who can claim membership in families of that number are the mighty names of George Washington, Daniel Webster, Samuel Portland Chase (whose father, we may observe in passing, was one of nine sons), Henry George, Thomas Carlyle and Oliver Cromwell.

Of those historic characters who were members of families nine in number, illustrious examples are Thomas B. Macaulay (whose father was one of thirteen children and whose grandfather was one of fourteen children), Charles Sumner, General Sam Houston, Albert Sidney Johnston, Robert E. Lee (whose father was one of eleven children, Patrick Henry and ex-president Grover Cleveland. Mr. Cleveland's ancestry is one truly remarkable for the very numerous offspring of which his progenitors became parents for generations reaching back to colonial times—far the most remarkable of all we have discovered. Moses Cleveland, a remote ancestor of the ex-president, was the father of eleven children; his son Aaron was the father of ten; the latter's son Aaron was likewise the father of ten; this Aaron's son of the same name was also the father of ten; a son of the third Aaron, also of the same name, could claim an additional son for each of the three preceding him, for he was the proud parent of thirteen children; a son of this Aaron, named William, became the father of Richard, who in turn became the father of Grover. It is thus apparent that Mr. Roosevelt's warm interest in the ex-president springs not altogether from a high opinion of his talents or his services.

Thomas Jefferson, Thomas H. Huxley and Charles Dickens were each one of eight children, while James Madison, Henry Clay, Samuel J. Tilden, Paul Jones, Martin Luther, William Wadsworth Longfellow and William Cullen Bryant were members of families consisting of seven. As characters coming from families of six we find W. H. Seward, Lewis Cass, John Milton, Thomas DeQuincey, William E. Gladstone and Rufus Choate, while Noah Webster, William Wordsworth, Cardinal Richelieu, John Keats, James Russell Lowell, Ralph Waldo Emerson, Robert Fulton, Gustavus Adolphus and Louis Agassiz—a goodly company, it must be owned, but only three more than those springing from families of ten—were each one of five children. The number four lays claim to the names of Charles Francis Adams, the Duke of Wellington, Henry D. Thoreau, John G. Whittier, Balzac and

Christopher Columbus, but of Whittier it must be added that his father was one of eleven children, his grandfather one of nine children and his greatgrandfather one of ten children. Constituting one of a family of three was Abraham Lincoln, Edgar Allen Poe, David Hume, Victor Hugo, Robert Browning and Edmund Burke. Albert Gallatin, Alexander Pope, Lord Byron, J. J. Rousseau and Aaron Burr make up the personages who can claim but a single brother or sister, though the mother of Alexander Pope, it is worthy of mention, was one of seventeen children. William M. Thackeray, Robert L. Stevenson, John Ruskin (whose father was likewise an only child) and Alexander Hamilton were single offspring.

A studied effort to swell the larger numbers by reference to biographies other than those mentioned would, it is needless to say, have added many a name to the lists, and fuller inquiry might show that of those whose names appear among the smaller numbers not a few could boast an ancestry noteworthy for numerous offspring, as in the case of Whittier, Pope and others. It has not, however, been our purpose to warp biography in the remotest degree to support or to refute a theory.

By casting together the historic names we have given and dividing the gross number of children by the total number of names we arrive at a figure a fraction less than seven—a number which we believe the statistics of population will show to exceed by not a little the number of children in the average family. It is true, of course, that statisticians, in computing the average number of children in families at large, would consider in the calculation families wholly without children, which would make the disparity less glaring—none the less the average progeny in families from which eminent personages have sprung would still be so large as to be striking.

It is apparent, upon a careful study of the figures we have given, that those who were members of large families were in general distinguished for great firmness of character—such as Napoleon, Peter the Great, Cromwell, Nelson, Washington and others. This is perhaps explained by the self-dependence one of many children reared by the same parents would acquire in the course of his youth; and the necessity of accommodating his enjoyments to those of his numerous brothers and sisters would serve a highly useful purpose in teaching him self-control, and also, perhaps, in teaching him resourcefulness. Among those, on the other hand, who were single children, or one of but two or three, no few displayed precisely the opposite qualities. However, we indulge in no theories—we call attention to the facts merely. Some reader of inquiring mind, perhaps, may be tempted to explore the subject farther.

THE PROBLEM OF AGE, GROWTH AND DEATH

BY CHARLES SEDGWICK MINOT, LL.D., D.Sc.

JAMES STILLMAN PROFESSOR OF COMPARATIVE ANATOMY, HARVARD MEDICAL SCHOOL

V. REGENERATION AND DEATH

Ladies and Gentlemen: In the last lecture I treated the conception I had formed of the processes of regeneration and told you that I looked upon the change which occurred first in the developing germ as one of rejuvenation. The process has for its technical name the segmentation of the ovum. The appearance of this segmentation process was illustrated to you by the pictures thrown upon the screen. Cytomorphosis is a term which we have frequently used in the course

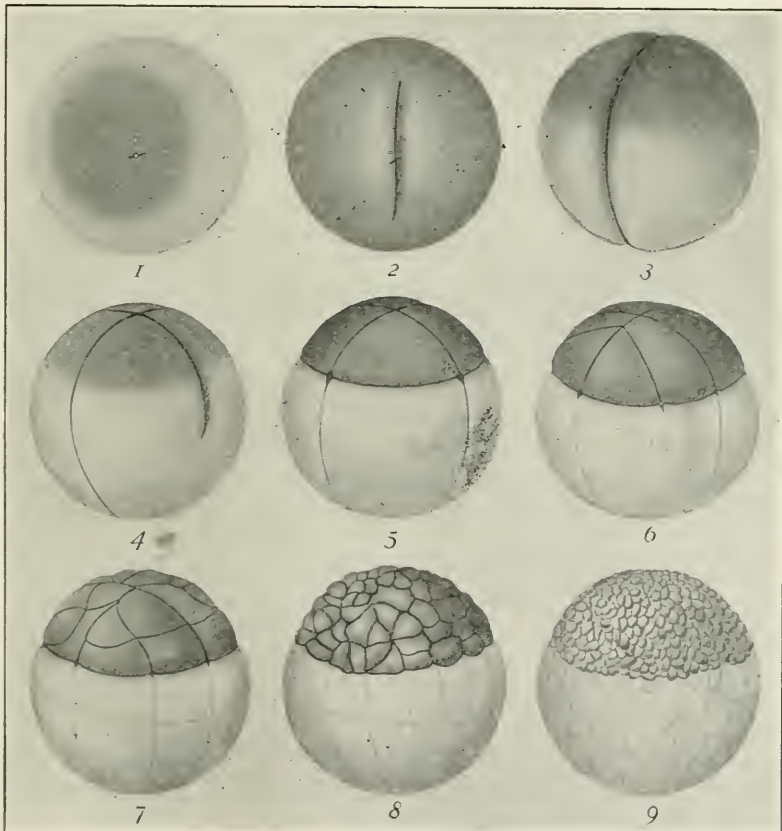


FIG. 51. THE SEGMENTATION OF THE OVUM OF *Amblystoma punctatum*, to show the earliest phases of development in the egg of a newt. After A. C. Eycleshymer.

of these lectures, and I have led you, I hope, to the appreciation of the idea that in cytomorphosis we have at least a part of the explanation of old age. We have learned that the young cells which are produced by the segmentation of the ovum in the body in large part changed into old cells, and also that old cells can not go back in their development and again become young; so that one might easily be led to the suspicion that there could be no possible new young, a conclusion obviously absurd, for there is a constant renewal of the generations. Some

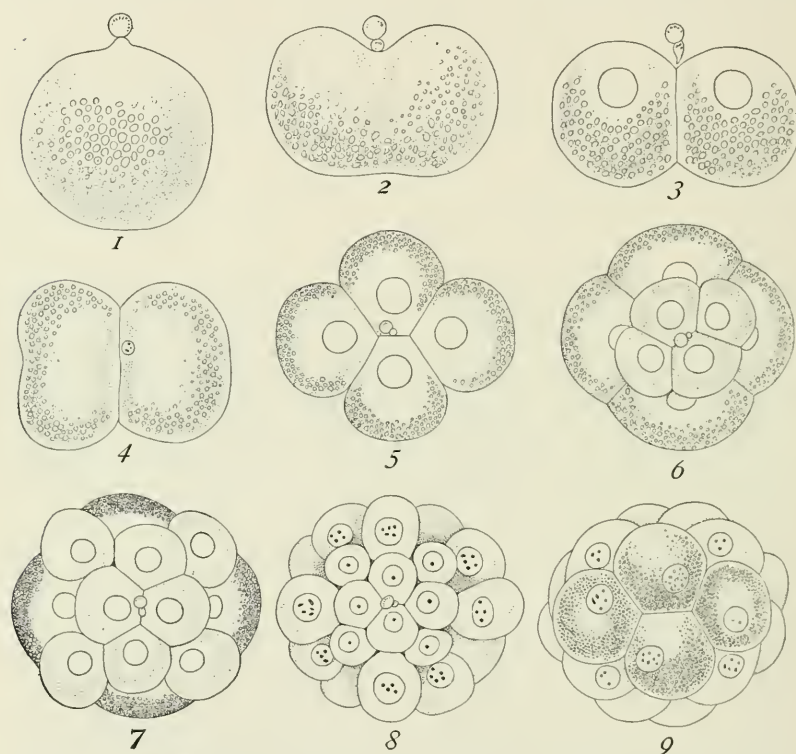


FIG. 52. THE SEGMENTATION OF THE OVUM OF *Planorbis*, to show the earliest phases of development of the egg of a pond snail. After Carl Rabl.

device, therefore, must exist by which that which is young is perpetuated, for that which is old can not again become young, and of that device I should like to say something this evening.

As a preliminary to the discussion of this interesting phenomenon, it is necessary to say a few more words in regard to the nuclei. You recall that the units, out of which the body is constructed, the cells, consist each of a little mass of protoplasm with a central body called the nucleus; and you will, I hope, recall that the increase of the protoplasm and the subsequent differentiation of the cell we looked upon as the cause of old age, and the increase of the nucleus as the cause of youth, of rejuvenation. In addition to what has been said concerning

the size of the nucleus, some further explanation is necessary, and that can best be given with the aid of some illustrations upon the screen. The first of the pictures will, I hope, serve to recall to your minds what I said in regard to the process of the segmentation of the ovum. Here is an ovum, No. 1, a single cell, but relatively of enormous size, the ovum or germ of a newt, and the plate illustrates to us the gradual process of division of the original single cell into a number of distinct cells, and each of these we call a segment, and the formation of them, segmentation, a name which we keep from the olden time when the process was first observed by some French investigators, because it is so descriptive of the appearance presented to the eye by the changes which are going on. Were we to name the process now we should certainly call it a process of cell production.

The next of our pictures shows us the eggs of a common snail, the Planorbis, a little fresh-water snail, the coils of which lie flat in one plane—hence its name. No. 1 is the original germ; No. 2 shows it about to divide into two; No. 3 is a side view; No. 4 a top view of the ovum with two segments; No. 5 is cleft into four segments; No. 6 into eight. Nos. 7 and 8 illustrate the further progress of the cell multiplication: No. 9 represents the under side of the same egg of

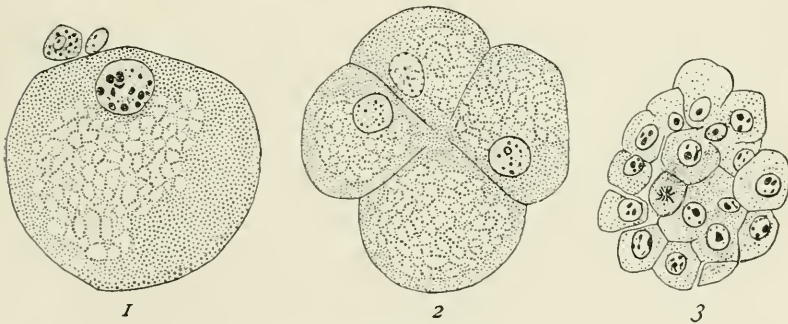


FIG. 53. THREE SECTIONS THROUGH THE SEGMENTING OVA OF A MAMMAL, *Tarsius spectabile*. 1, ectoderm; 2, mesoderm; 3, entoderm; 4, Hensen's knot; 5, entoderm; 6, mesenchyma; 7, entoderm; 8, medullary groove; 9, ectoderm; 10, large motor neurone; 11, spinal ganglion; 12, mesenchyma; 13, cartilage; 14, Wolffian body; 15, kidney; 16, striated muscle; 17, heart muscle; 18, esophageal entoderm; 19, tracheal entoderm; 20, liver; 21, entoderm; 22, motor neurone; 23, spinal ganglion; 24, dermis; 25, hypodermis; 26, cartilage; 27, 28, Wolffian tubules; 29, pelvis of kidney; 30, heart muscle; 31, esophageal entoderm; 32, tracheal entoderm. After A. A. W. Hubrecht.

which the top is figured as No. 8. The number of cells (segments) is thus constantly increasing and already it is evident that they have become somewhat unlike in character. Were the picture still further magnified, we could see that in these cells a change is going on in the nuclei which, however, I can better demonstrate to you by means of the following picture, one which we saw in the last lecture. These are sections through the early developing germ of a mammal named *Tarsius spectabile*. It is a creature nearly related to the lemurs, having

a special interest to naturalists, owing to the fact that in its early development it offers features of resemblance to man which are very striking and instructive. The plate is from a series of drawings made under the direction of Professor Hubrecht, the principal student of the development of this type of animal. Here (No. 1) we can see an early stage in which the germ consists of but a single cell, and at this point is the nucleus. Note its size and then compare it with the nuclei in Nos. 2 and 3 in which several of these cells, as they appear in a section, are represented. The cells themselves are now smaller because they have multiplied by the division of the original germ, but the nuclei in them are likewise smaller. And in the older stage, No. 3, where the number of cells has begun still further to increase, we see that there is another and more marked reduction in the size of the nuclei. Contrast the single nucleus of the early stage with the small nuclei of the later one, and notice how very striking is the change in the size. Thus during the early development of the individual, and it seems to be true of all animals, we find that there is an actual rapid reduction in the size of the nucleus. As we have learned that the proportion of the nucleus and the protoplasm is so important, we must attribute to this alteration in the dimensions of the nucleus great significance.

We have next a series of figures which have interested me very much and which I only recently secured as the result of studies I have been making in my own laboratory at the Harvard Medical School. These pictures are now shown publicly for the first time, and record a fact which, so far as I know, has never yet been clearly noted and recognized as important by any investigator. The four figures at the top represent four single nuclei taken from different parts of a rabbit seven and one half days after the commencement of its development. The second set of figures, 5, 6, 7 and 8, show nuclei from different characteristic parts of a rabbit embryo of ten days. Note, please, the size of these nuclei, the curious network of threads in their interior and the existence, generally more or less in a central position, of a mass of material which stands out conspicuously and represents a condensation of the nuclear stuff at that particular point. Such a central body is highly characteristic of these early stages. Next we come in the series of figures, from 9 to 20, stretching across the screen in two lines, to a rabbit embryo of twelve and one half days. Instead of having nuclei of large size we have now nuclei which are obviously small. Instead of having nuclei which are more or less alike in appearance, we have now nuclei of great diversity. Every one of these figures, as you will readily see if you run your eye along from one end of the lines to the other, has a distinctive character of its own. In this period, then, of two and one half days, there has been a revolution in the character of the nuclei of the developing embryo. Where before the nuclei were alike, now they have become unlike. Two of these I

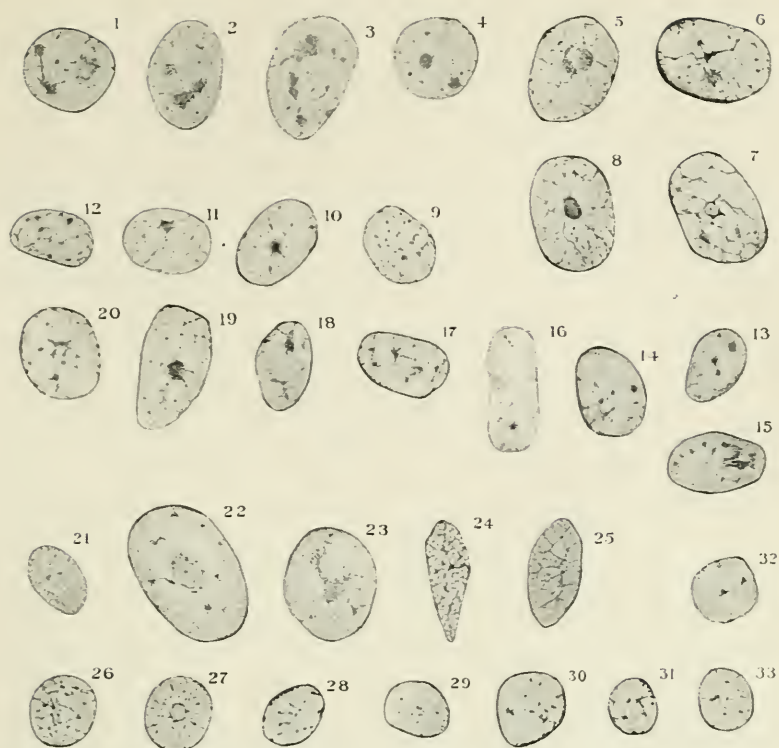


FIG. 54. NUCLEI FROM RABBIT EMBRYOS. 1-4, age, seven and one half days. 5-8, age, ten days. 9-20, age, twelve and one half days. 21-33, age, sixteen and one half days.

should like especially to call your attention to, because they are the nuclei of the nerve cells—this one, No. 11, from the spinal cord and the right-hand one, No. 10, from the cluster of nerve cells upon the root of a spinal nerve. Finally, we have the series of figures from a rabbit of sixteen and one half days represented in the two lower rows, 21 to 33. In these, if you will leave aside from consideration for the moment 22 and 23, which are obviously of a different size, all are now smaller than they were at twelve and one half days. Every one of the nuclei here represented is characteristic. We have here, for instance, nuclei of the excretory organ; a nucleus of the connective tissue; we have nuclei from the lining of the wind-pipe and the lining of the gullet. Every one of them differs from every one of the others pictured. But if we had drawings of a number of nuclei from the same part of the body and same kind of tissue, we should see that they would be essentially similar. We learn then that there is acquired a great diversity in the structure of the nuclei as well as in that of the protoplasm, of which we have seen so many examples in the previous lectures. You will recall, that as regards the size of cells the nerve cells present a noteworthy excep-

tion in that they differ according to the size of the animal; and their nuclei differ also, for as the cells become big the nuclei grow likewise. Here are nerve-cell nuclei in the rabbit of twelve and one half days not differing in their dimensions essentially from the nuclei of other types, but in the two lower figures, 22 and 23, we see nuclei corresponding to the cells of the rabbit at sixteen and one half days. These cells have begun to enlarge, to assume the greater dimensions of the nerve cells, which is characteristic of the rabbit; and accompanying the enlargement of the cells there has been an expansion of the nuclei also. But this does not affect, as you will readily see by the pictures upon the screen, the nuclei of any other sort of tissue, the nuclei of any other organ of the body.

We must therefore add to our conceptions in regard to the relations of the nucleus and protoplasm, as quantitatively expressed, this further notion that there is during the early period of development an actual reduction in the size of the nucleus. When this reduction has taken place it is of course evident to any one at all acquainted with the principles of cytology that the cells are in a very different state from what they were in before. They are no longer such cells as they were when the nucleus was large, and the nuclei in the different parts of the body alike in character. Here the relations are fundamentally changed. We do not find that these nuclei ever get back from the complex variety of organization which they present to us in later stages to the earlier condition when they were all alike; yet only with cells of this uniform sort can development begin. We should therefore, if we reasoned only from the data which I have thus far presented to you, come to the conclusion that reproduction would be impossible, that the cells of the body, having been so changed, as we have seen, are no longer capable of returning backwards along the path they have journeyed; they can only remain where they are, or go yet further onward in the career of cytomorphosis. Nature, however, has met this difficulty by a way which we have only recently discovered. We are not yet sure that the way we have discovered is the only way, that it is the universal method in the case of all animals for accomplishing the purpose. The discovery of this method of providing for the perpetuation of youthfulness from one generation to another, the youthfulness of the cell of man, is due to the investigations of Professor Nussbaum, of Bonn. The theory, which he put forward, has been verified by subsequent examinations and investigation, and confirmed, I am glad to say, in part by some very interesting and careful observations which have been made here in Boston. Perhaps the very best confirmation of all is the recent extension of our knowledge in regard to this theory which comes from the investigations of Dr. B. M. Allen, made at Madison, on the process as we find it in the developing turtle. It is really essentially a very simple thing. Nature seems to take some of the cells which are in the

primitive condition, with the protoplasm still undifferentiated and the nucleus of the embryonic or simple organization, and hold them apart from the rest of the body, not separating them so that they come off and leave the body, but so that they have a different history; so that they escape the change which the other cells of the body must pass through. These cells of a simpler character are gathered together, kept asunder, and not allowed to progress in the development of all the cells which form the body proper. We have learned, for instance, that in the development of the dog-fish very early, before any organs exist, cells are formed into a cluster. They lie by themselves, are easily recognized under the microscope, and they have obviously the primitive character which I have endeavored to explain to you. And they remain such. Meanwhile as development progresses, all the remaining cells—all those not part of these clusters, pursue their proper careers, become differentiated; but the cells in the clusters do not change for a long period. Later as the organs become differentiated, we can recognize in the direct descendants of these cells, which have been traced from stage to stage so that their history is known with certainty, those cells which in the adult we call the germ cells, and which are to serve for the reproduction of the species. These cells are set apart at all periods. They represent germinal matter which is withheld from the metamorphosis which the rest of the body undergoes. They have a continuous history. Hence we bestow upon this method, under the conception that it is applied to secure propagation of the species, the term—theory of germinal continuity. It is the theory of hereditary transmission which I think is now universally held by all competent biologists. Our study of nuclei and of their relations to protoplasm serves to clear up in our minds, it seems to me, to some degree at least, the necessity which really exists for this device of germinal continuity, of the setting apart of certain cells of the rejuvenating sort, of the young sort, of the embryonic type (the term you apply to them matters little), which cells are those used to produce the new offspring of the next generation. All this, of course, fits perfectly with the doctrine which I have been telling you of again and again in this course of lectures, that the progress of differentiation is always in one direction and ends in the production of structure which, if it is pursued to its legitimate terminus, results in the degeneration and death of the cell. Obviously such a set of changes as I have thus indicated can not produce the sort of a cell which is necessary for reproduction.

I wish there were time to enter more fully into this question of the size of nuclei, for there is much which might be said concerning it. This much more, however, ought to be said to you—that the problem of the size of nuclei is by no means a simple one. It has been found, for instance, in the experiments made upon some of the simple algæ, the so-called *Spirogyra*, which every elementary student of botany probably

has looked at in the laboratory, that by certain artificial conditions, as made in the experiments of Professor Gerassimow, the size of the nucleus can be changed in the cells, and when the size of the nucleus is changed, the size of the cell alters also. And again, we know that the nucleus provides certain chemical supplies for the life and functioning of the cells. This is very strikingly the case, for instance, in regard to the cells which secrete. These, when they give off the material which they have accumulated in their protoplasm as a preparation for the act of secretion, are found not only to reduce the bulk of their protoplasmic bodies, but the bulk of the nuclei as well. And we know again that the size of nuclei may be changed by somatic conditions, by food supply, so that in every generalization reached by the study of the size of nuclei, we must be very circumspect, and not fancy too easily that we have reached a safe conclusion unless we have taken into consideration all the possible factors by which the size may have been varied.

In what I have said to you hitherto in regard to the power of growth, I have directed your attention chiefly to the power of growth as it exists in a cell in consequence of that cell's condition. When the cell is in the young state, it can grow rapidly; it can multiply freely; when it is in the old state it loses those capacities, and its growth and multiplication are correspondingly impeded, and if the organization is carried to an extreme, the growth and the multiplication of the cell cease altogether.

We find, however, that there is something a little more complicated yet to be considered, for it is not merely a question of the capacity of the cells, but also of the exercise of that capacity, which we must deal with. Here comes in a factor which we learn from the study of regeneration. The phenomena of regeneration are very important and very instructive. We shall come to those in a moment. It will make our study of regeneration clearer, more significant, I think, if we pause for a moment to consider certain fluctuations in the natural development of the organism. We see, for instance, in the brain that early the cells begin to assume the character of nerve cells and that thereafter their multiplication ceases. But, curiously, there will be a spot in the spinal cord, for example, where the change of the cells into nerve cells has not taken place, and from that growth will go on. Cells will migrate from that spot and reach their ultimate destination. When the child is born it is very incapable of movement. There is scarcely more than the power of twitching about in a disorderly fashion. Its muscles can contract, to be sure, but any sort of motion that implies a harmonious working together of various muscles, the baby at birth is quite incapable of. This phenomenon is doubtless due to the fact that the cerebellum, the small brain, is as yet imperfectly developed. If we examine the brain of the child at birth, we find at the edge of the cerebellum a line

along which the production of new cells is going on. These new cells migrate over the surface of the cerebellum without changing at all into nerve cells. They form a distinct layer which is well known to every investigator of brain structure, and presently after birth these cells accomplish a second migration, but in a different direction. Instead of moving in a constant current over the surface of the brain, each one takes a vertical pathway from the surface down towards the interior of the cerebellum; and arrived there it changes and becomes a nerve cell, or at least a part of them do; and with that the machinery of the cerebellum is complete. Thus, structurally, the cerebellum at birth is an uncompleted organ. Now, the cerebellum is that portion of the brain which regulates the combination of muscular movements, which secures that which the physiologists term coordination of movements, and it is not until the cerebellum has been perfected that it can perform this function. Were there not some provision of this special sort for allowing cells to be produced and added to the brain, the full complexity of the brain could not be attained, because after the cells have begun to change into nerve cells they lose their power of multiplication, and this is a device very exquisite in its working to supply to the brain the requisite number of cells to give it its full measure of complexity.

Another instance of the reservation of cells of a simple type is afforded us by the skin, about which I shall have something more to say in a few moments when we speak of the process of regeneration. It is not only in the period of childhood, and not only in the cerebellum, that we find cells exist such as I have just described to you, but it is in other parts of the body also and at other periods of life that we find the like phenomena; and in part I have already referred to these. You remember I told you in a previous lecture there is always in the body, even at the extreme of life, a store of cells of the young type, which is garnered in the marrow of the bones. The cells in question can multiply, and their descendants in part undergo a change in consequence of which they are converted into blood corpuscles. The undifferentiated or young cells are preserved in the marrow precisely for the purpose of making up the necessary number of blood corpuscles to replace those which are lost either by accident or in consequence of normal physiological processes. I mentioned to you that in the lining of the intestine there is a constant loss of cells and we find in every simple gland of the intestine, in every little gland of the stomach, a center for cell production, a center where there is a group of cells which are not differentiated, but retain their simple organization.

I could multiply these instances almost indefinitely, but perhaps it will be better to call your attention to an illustration of quite a different sort. We know that in order to have a very complex organization, the number of cells in the body must be very large indeed. Obviously a

small insect, a mosquito or a little beetle, whatever it may be, is not big enough to have a great many cells; and, unless it has a great many, it can not attain the differentiation of complicated organs such as we possess. Now, the lower animals are born, so to speak, early, and as soon as they hatch out, they have to support themselves. We see that, for instance, in caterpillars. They are born very little creatures, but each caterpillar must look out for itself, obtain its own food, move about to that food, must, when the food is swallowed, digest it, and must carry on the correlated functions of secretion and excretion; it must breathe. In order to do all this the larva, or young caterpillar, to follow our special instance, must have some differentiation already established; but, as we have already learned, differentiation impedes growth. In other words, in such a larva the multiplication of cells is held back by the very demands of the conditions of its existence. If it is to have organs which are to function, it must have differentiated parts, and, if it is differentiated, its growth power must be sacrificed.

Now how has nature proceeded in order to produce a higher type of animal, one in which the number of cells is much greater? Very ingeniously. She provides the developing organism with a food supply which it carries itself. If, for instance, you recall the egg of the salamander, which I showed you upon the screen, you will remember that that is a structure of considerable size, and its size is due to the accumulation of food material, material which we designate by the term yolk granules, which lie in the living protoplasm of that germ. This supply of food is so great that it will last the organism a considerable period. While it is growing it has nothing to do but to digest that food supply which it already possesses. It does not have to exert itself to obtain it, and no further digestive process is necessary than that inherent in all living protoplasm. So the young salamanders develop in a most advantageous condition, and can actually produce a much greater number of cells because it is possible, with this internal food supply, for the growth to go on only with the cells of the embryonic or youthful type for a considerable period, and then, when their number has considerably increased, steps in the process of differentiation.

In the higher animals this accumulation of food for the nourishment of the germ is carried yet further. As you know, the egg of the bird is much bigger than that of the salamander, and in the highest animals, in the mammals, there are other special contrivances which nature has introduced to secure ample and adequate nourishment of the developing germ. There the perfection of the process is made yet greater and in these forms there is a long period during which the production of cells goes on; the cells all remain simple, and by the time they begin to change the number of cells is so great that the possibilities of an infinite variety, almost, of peculiarities in them are given, and

there are cells enough to allow this variety to be worked out. This we call the embryonic type of development.

We see, therefore, that nature has recognized a restriction which she herself has put upon development, the restriction which obliges development, if it is to be ample, to prolong the accumulation of the undifferentiated cells. In response to that condition, she substitutes for higher types of animal that development which we call embryonic, leaving for the lower type that which we call larval. Thus we see in the growth and formation of the higher animals and in the history of the comparative development of the animal kingdom, fresh illustrations of the great importance of the young type of cells.

We can see the same thing also in regard to regeneration. The regenerative process depends to a large extent upon partial differentiation, or even upon its total absence. Regeneration is a most interesting and wonderful process. I took pains only this afternoon to look at that famous classic by the Dutch Abbé Trembley on hydroids or polyps as he calls them. "The Fresh Water Polyps," a book published in 1744, was well printed, and on such good paper that it looks to-day

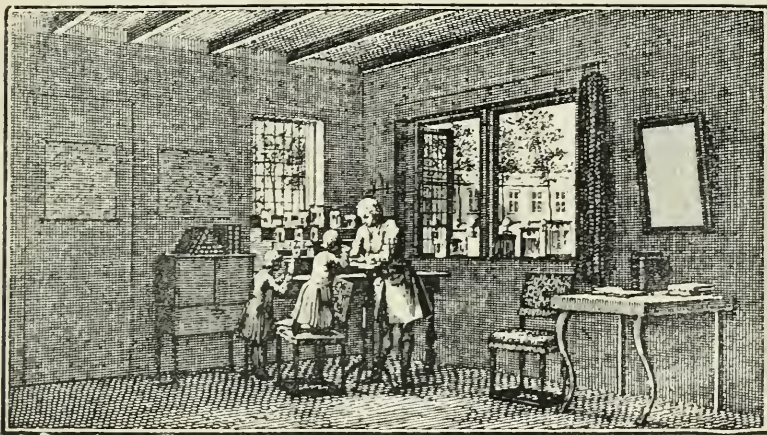


FIG. 55. VIGNETTE FROM TREMBLEY'S CLASSIC MEMOIR, representing Trembley making his experiments on regeneration in fresh-water polyps.

almost like a new book. He made the curious experiment of cutting one of these minute fresh water polyps—they are perhaps an eighth of an inch long—in two, and made the startling discovery that each half of the polyp would make up what the other half had deprived it of; each half, in other words, would become a new polyp. That which was lost was regenerated. After him came a series of yet more remarkable experiments by the famous Italian naturalist, Spallanzani, one of the masters of experimental research, and he discovered that regeneration was a property which was not peculiar by any means to polyps,

but existed in the earth-worms, and even among vertebrates; for he it was who discovered that if the head of an earthworm be cut off, the worm will form a new head with a new brain and a new mouth. He first discovered that if you cut off the tail of a salamander a new tail will grow out. He it was, moreover, who discovered that this power of replacing the lost part is greater in the young—greater in the earlier stage than in the later. This indicates in a general way the nature and process of regeneration. We have many kinds of regeneration; we may have that of the single cell or that of the whole organism.

We pass now to the next of our slides, which represents a creature of the kind called *Stentor*. It is a single cell. Here is the nucleus of

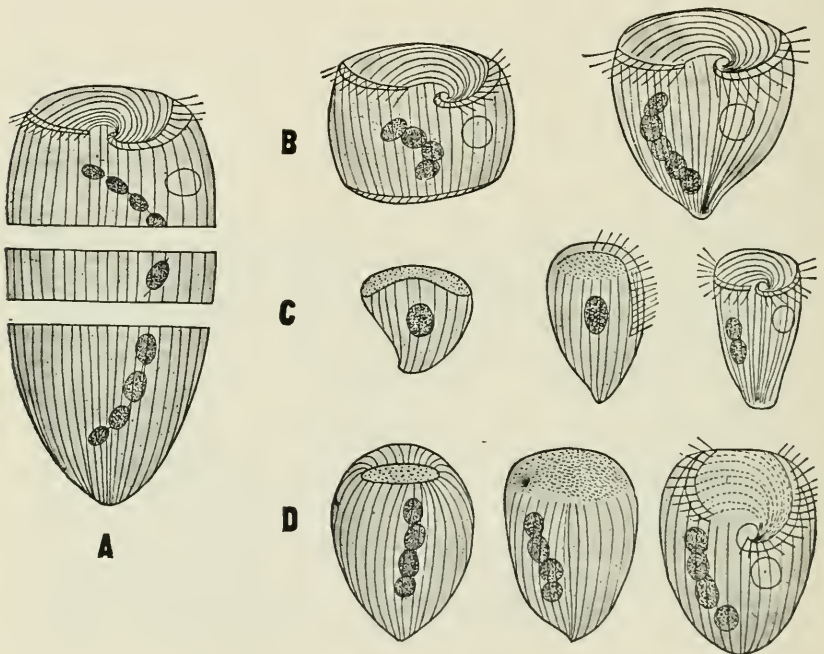


FIG. 56. *Stentor*.

the cell; its protoplasmic body is large, and something of the structure of this I have told you in a previous lecture. A German investigator, Professor Gruber, has succeeded in dividing one of these *Stentors*, a unicellular creature, animalcule, common in fresh water, into three parts in such a method of cutting as is illustrated by the figure on the left. Each of the three parts will then restore itself and become a complete *Stentor*. In such experiments the protoplasm over the nucleus begins to grow; gradually the original form is again assumed; the creature grows larger and larger, until each piece acquires the parent size, and, so far as we can see with the ordinary microscopic examination, identically the parental structure. That which was lost

has been regenerated. We learn, then, that regeneration is a faculty which a single cell, a single unit, may possess.

Our next picture demonstrates a similar phenomenon. These are muscle fibers which have been injured. Now every muscle fiber contains in its interior its contractile substance, in regard to which I have already spoken to you, but it also contains a certain amount of substance which is still undifferentiated protoplasm. Now when a



FIG. 57. STRIATED MUSCLE FIBERS IN PROCESS OF REGENERATION.

muscle fiber of this sort is injured, we find that the muscular structure, properly so called, will in many cases quite disappear. but then the protoplasmic material, which is the undifferentiated substance, will begin to grow, and the nuclei will begin to multiply. This may happen at the end of a muscle fiber, producing there a considerable mass of protoplasm, with nuclei multiplying in it, or we may find a chain of nuclei, each with its separate court of protoplasm body: such nuclei will multiply. When the increase of the undifferentiated protoplasm has gone on far enough, the injured muscle will produce again the muscular substance proper—the contractile fibrils. Muscular fiber, in other words, can be regenerated by itself.

A similar thing to this happens when a nerve is cut across. The nerve fiber, which is connected with the nerve cell from which it arose, is capable of growing out again. It can regenerate itself, and that is a well-known phenomenon, and in many surgical cases it becomes a phenomenon of very great importance.

Let us go back to another familiar figure. Here is represented the lining layer of the œsophagus with the cells composing it, the upper ones being horny, the lower ones those which are capable of active

growth. We are rather dull. We do not often stop to think about things. We buy a new horse which comes from the country, has never seen a train; drive him to the station, and are frightened, perhaps, because the horse himself is so much alarmed—possibly have a narrow escape because of the excitement which his first sight of a train causes him. But that horse, after a few months' discipline, will scarcely turn his ear, much less his head, to look at the train which a short time before so frightened him and held his attention that nothing else could get into his mind save the fright that train gave him. So we, too, act a good deal like the horse. We see a thing the first time and it surprises us; the next time it seems like an old acquaintance, a thing

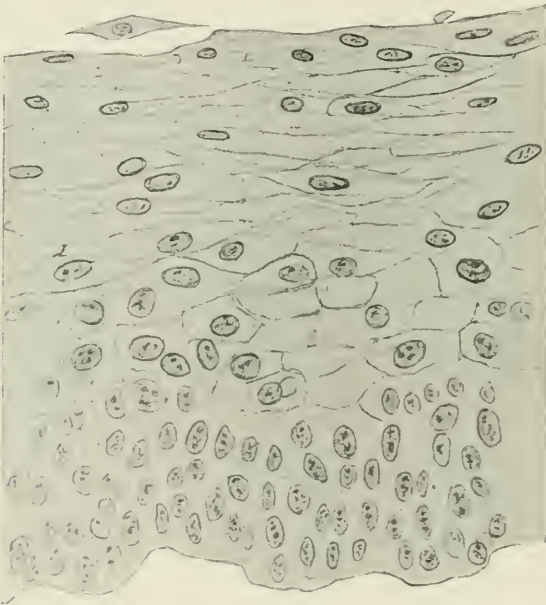


FIG. 58. SECTION OF THE EPITHELIAL LINING OF THE HUMAN OESOPHAGUS.

familiar and therefore unregarded. I say this apropos of the skin. How many of you have thought what the lesson of the skin is in regard to the power of growth? Spring is coming; we shall soon be taking to our boats, rowing or canoeing, and the first day we do so doubtless we shall have blisters upon our hands, and the outer part of the skin, raised by the blister, will probably fall off and be lost altogether. The softer, underlying skin will be exposed, will be sensitive and uncomfortable for a while, but soon the cells behind the surface will assume a horny character, the cells underneath will grow and multiply, and presently the wound will be healed over. Did you ever stop to think that that means that there is a reserve power of growth in the skin all the time? always ready to act, to come forward, waiting

only for the chance, and that there is besides something which keeps it in, which holds it back, which stops it? We call this stopping physiological function—inhibition; we say that the growth of the skin is inhibited; though in the deep part of the skin all the time there are the cells ready to grow as soon as that power of inhibition is taken away; while it is active they will not grow. The simple blister tells us all that. There is, then, a power of regulation which expresses itself in this inhibitory effect. When a salamander has its tail cut off by the experimenter and the new tail grows, just enough is produced. The new tail is like the old. The tissues grow out until the volume of that which is lost is replaced, and then they stop. But if the tail should be cut off again, regeneration would occur again. The experiments may be repeated many times over. It indicates to us that always the growing power is there, but it is held in check. What that check may be is one of the great discoveries we are now longing for. The discovery, when made, is likely to prove of great practical importance. The phenomenon of things escaping from inhibitory control and overgrowing, is familiar. Such escapes we encounter in tumors, cancers, sarcoma and various other abnormal forms of growth that occur in the body. They are due to the inherent growth power of cells kept more or less in the young type, which for some reason have got beyond the control of the inhibitory force, the regulatory power which ordinarily keeps them in. No picture of the growth or development of the living animal would be complete if it confined its attention only to the power of growth in relation to cytomorphosis. It must also include the contemplation and study of this regulatory power of the organs. Experiments are being made in many places, minds are at work in many laboratories upon this problem of regulation of structure and growth. Much is to be hoped from such researches; not merely insight into the normal development, but insight also into the abnormal. Nothing, perhaps, is more to be desired at the present time than that we should gain scientific insight into the regulatory power which presides over growth. It would be of immense medical importance. Could we understand it, and could we from our understanding derive some practical application of our scientific discoveries in this field, we could say of it justly that it was as noteworthy a contribution to medical knowledge as the discovery of the germs of disease, and would doubtless prove equally beneficial to mankind. Although, then, the study which I have been laying before you must necessarily seem in many respects abstruse and far away from practical applications, we learn that it is not really so, and that it leads by no very remote path to the consideration of problems the useful applications of which are immediately obvious to every one.

We find in the process of regeneration that it is always the young cell which plays the principal part. This is beautifully illustrated in

the picture upon the screen. There is a little creature, which many of you have seen in the garden, consisting of joints, which rolls itself up into a little ball, and therefore is often called the "pill-bug." It is not, however, an insect or a bug, properly so-called, but belongs to a family of crustaceans. It has on its head a little feeler which we call the antenna. The particular kind of arthropod, the antenna

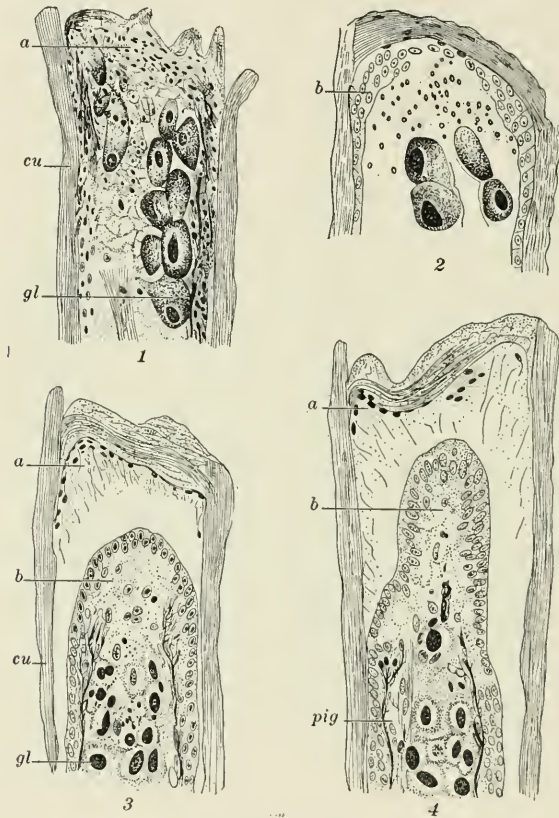


FIG. 59. SECTIONS THROUGH THE ANTENNA OF *Oniscus* IN VARIOUS STAGES OF REGENERATION AFTER AMPUTATION. After Ost.

of which has been studied and drawings of it made to furnish us this plate, is known by the name of *Oniscus*. In his researches the experimenter, Dr. Ost, cut off the antenna in the middle of a joint and found that it rapidly healed over. Here is pictured the process of healing going on. Part of the antenna has been cut off in this case, the wound was healed over here, No. 1, *a*, the new tissue has begun to grow, No. 2, *b*, and the cells at this point are very simple in character. They spread out and grow, and then, within the interior of the hard shell of the feeler, a retraction of the substance occurs, and the new growing cells within this space gradually begin to shape themselves out,

No. 3, *b*, and we see presently an accumulation of cells which is assuming a definite form, No. 4, *b*, that in the next figure has clearly become the promise or beginning of a new terminal joint, Fig. 60. The minute study of this process has shown that the regeneration depends practically exclusively upon the cells of the young type, and that after they have grown out and accumulated here in this manner, No. 3, *b*, some of them undergo differentiation, becoming muscle cells; others change in the manner indicated here, where we see a commencing alteration of the nuclei, which is further accented in Fig. 60, and leads to such a grouping of the cells that the glands, which were originally present there, are also reproduced. The regenerative process, then, clearly illustrates to us from another point of view the great importance of the young type of cells.

This completes the evidence which my time permits me to lay before you in order to convince you that really the young type of cells is physiologically and functionally important, that it really does possess the power of growth such as I have attributed to it.

We will pass now to another part of our subject, with which the lecture will close. Age represents the result of a progressive cytomorphosis. We have learned that of cytomorphosis death is the end, the culmination. It is a necessary result of the modification and change of structure which goes on in every individual of our species and of all the higher animals. We are familiar with the death of cells. It occurs constantly and, as I have endeavored to explain to you, it plays a great part in life. It promotes the performance of various functions which are of advantage to the body as a whole, which could not be accomplished without the death of some cells. But the death which we have in mind when we speak ordinarily of death is something different from this. It is the death of the whole. But even the death of the whole has its strange complications. A great deal of our knowledge of the functioning of the body is due to the fact that the parts do not die when, as we commonly say, the body as a whole, the individual, is dead. The organ is alive and well. One

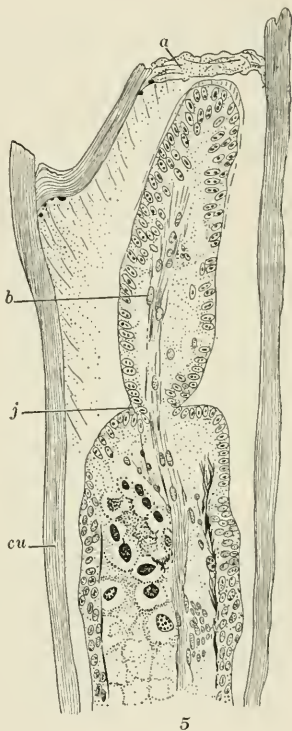


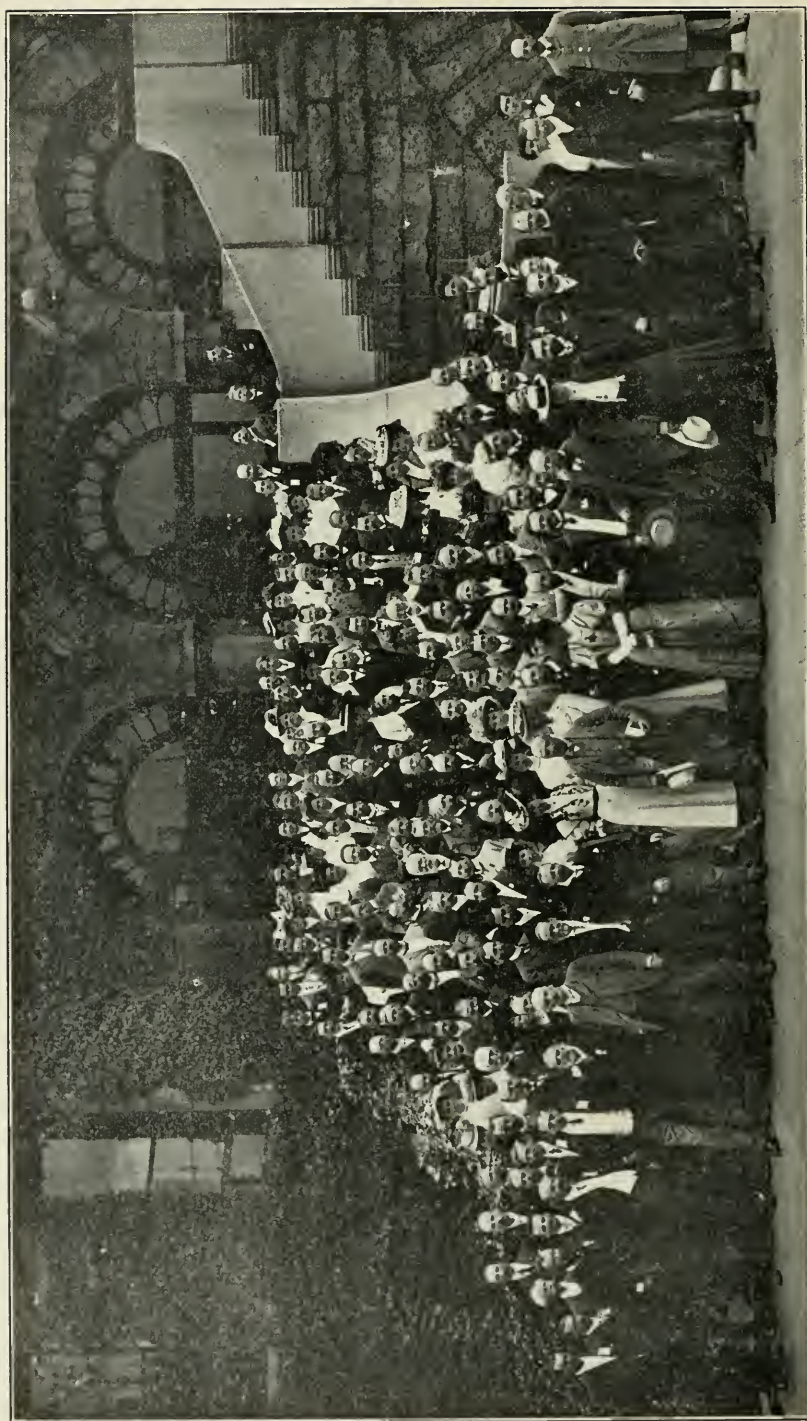
FIG. 60. SECTION THROUGH A REGENERATING ANTENNA OF *Oniscus*. After Ost. Advanced stage, in which the young new joint is already shaped within the old shell. *a*, cicatricial tissue; *b*, regenerated tissue; *j*, new joint; *cu*, cuticula (old shell). Magnified.

of the most impressive sights which I have ever seen has been the sight of the heart of a quadruped, a dog, continuing to beat after it had been taken out from the body. The dog was dead—the rest of his body was dead—but the heart lay upon the physiologist's table beating. The experimenter could supply it with the necessary circulation. He could give stimuli to it, and under these favorable conditions make important discoveries in regard to the functioning of the heart. So too I myself made experiments upon a muscle once part of a living dog, separated entirely from the parent body, supplied with its own artificial circulation, and from those experiments was able to discover some new unexpected results in regard to the nutrition of the muscle, and the changes which chemically go on in it. This over-living, then, of the parts of the body, their separate life, is something which we must familiarize ourselves with, and the great importance of which we must carefully acknowledge, for much of the benefit which the medical practitioner is able to render to us and to our friends to-day is due to the knowledge which has been derived experimentally from the study of the over-living or surviving parts of a body which as a whole was dead.

Death is not a universal accompaniment of life. In the lower organisms death does not occur as a natural and necessary result of life. Death with them is purely the result of an accident, some external cause. Natural death is a thing which has been acquired in the process of evolution. Why should it have been acquired? You will, I think, readily answer this question if you hold that the views which I have been bringing before you have been well defended, by saying that it is due to differentiation, that when the cells acquire the additional faculty of passing beyond the simple stage to the more complicated organization, they lose something of their vitality, something of their power of growth, something of their possibilities of perpetuation; and as the organization in the process of evolution becomes higher and higher, this necessity for change becomes more and more imperative. But it involves the end. Differentiation leads up, as its inevitable conclusion, to death. Death is the price we are obliged to pay for our organization, for the differentiation which exists in us. Is it too high a price? To that organization we are indebted for the great array of faculties with which we are endowed. To it we are indebted for the means of appreciating the sort of world, the kind of universe, in which we are placed. To it we are indebted for all the conveniences of existence, by which we are able to carry on our physiological processes in a far better and more comfortable manner than can the lower forms of life. To it we are indebted for the possibility of those human relations which are among the most precious parts of our experience. And we are indebted to it also for the possibility of the higher spiritual emotions. All this is what we have bought at the

price of death, and it does not seem to me too much for us to pay. We would not, I think, any of us, wish to go back to the condition of the lowly organism which might perpetuate its own kind and suffer death only as a result of accident in order that we might live on this earth perpetually; we would not think of it for a moment. We accept the price. Death of the whole comes, as we now know, whenever some essential part of the body gives way—sometimes one, sometimes another; perhaps the brain, perhaps the heart, perhaps one of the other internal organs may be the first in which the change of cytomorphosis goes so far that it can no longer perform its share of work, and failing, brings about the failure of the whole. This is the scientific view of death. It leaves death with all its mystery, with all its sacredness; we are not in the least able at the present time to say what life is, still less, perhaps, what death is. We say of certain things—they are alive; of certain others—they are dead; but what the difference may be, what is essential to those two states, science is utterly unable to tell us at the present time. It is a phenomenon with which we are so familiar that perhaps we do not think enough about it.

In the next lecture there will be some other general aspects of our subject to present to you, and a formulation of the general conclusions towards which all the lectures have aimed.



MEMBERS OF THE INTERNATIONAL ZOOLOGICAL CONGRESS AT THE AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK CITY.

THE PROGRESS OF SCIENCE

MORTALITY STATISTICS

THE Bureau of the Census has just issued its annual report on mortality statistics for the year 1905. There is surely nothing more dramatic than tables of death rates, however uninteresting they may appear to the casual observer. Thus the death rate in Indiana and in Michigan is scarcely above 13 a thousand, whereas in European Russia it is 33. If the population of European Russia is assumed to be 130 million, this means that of the 4,290,000 people who die annually in that country 2,600,000 would not die if the conditions were as favorable as they are in Indiana and Michigan. There is no reason to suppose that the Russians are naturally less vigorous than those living in our central states, and this great loss of life—besides which the number of those killed in the Russian-Japanese war is insignificant—must be due to conditions of life which could be remedied. It is probable that in the cases of the states quoted, and in some parts of Great Britain, Norway and Sweden where the rate is equally low, it is still very much higher than it should be. We may hope that the publication of the death rates may itself have a tendency to call attention to the enormous annual sacrifice of life, and it is consequently fortunate that the Bureau of the Census is now able to publish annually a volume of statistics and that the area covered by the statistics tends to increase.

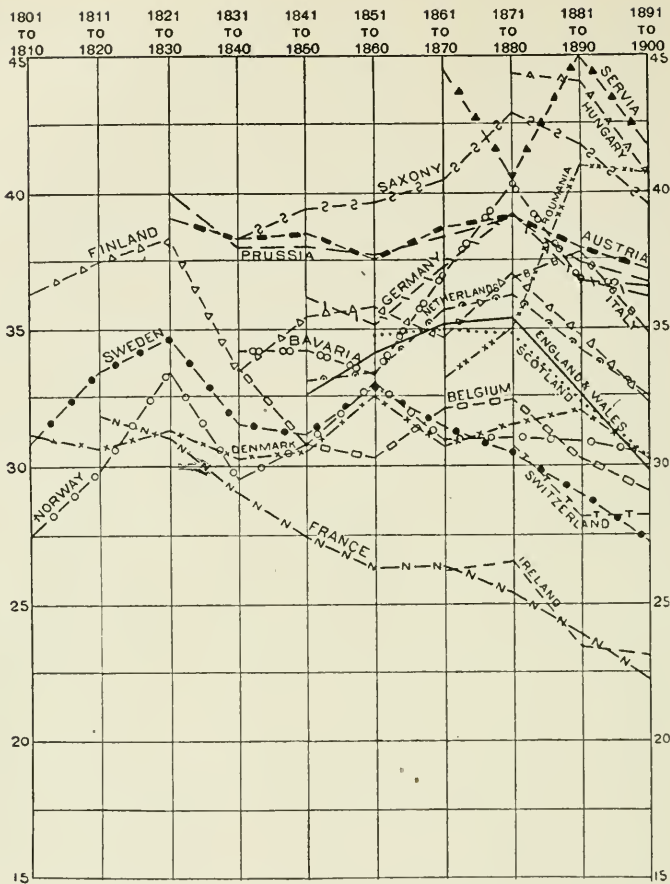
In 1890 the states in which registration was effective had a population of about twenty million, and in addition there were registration cities having a population of about ten million. In the year 1906 the states of California,

Colorado, Maryland, Pennsylvania and South Dakota were added to those which maintain effective registration. The population now included in the registration area is over thirty-six million, or nearly half the total population.

Indiana and Michigan have the lowest death rates among the registration states; the death rates being, respectively, 15.3 and 14.7 in their cities, and 12.7 and 12.8 in their rural districts. In New York City the death rate was 19.4 as the average of the five years from 1900 to 1904. The cities having the lowest death rates were St. Joseph, Mo., St. Paul, Minn., and Minneapolis, Minn., where rates, respectively, of 7.6, 10 and 10.6 are assigned. Charleston, S. C., has the highest death rate—31.3—but here, as in other southern states with abnormally high death rates, the incidence is on the negro population. The death rate at Charleston, for example, is 22.9 for whites and 44.3 for negroes.

Tuberculosis of the lungs is still by far the most fatal of all diseases, causing 172 deaths each year for each hundred thousand of the population. It is followed by pneumonia with 135, heart disease with 121, diarrhoea with 113, and nephritis and Bright's disease with 94. There is a tendency for diseases such as apoplexy and cancer, which affect mainly elderly persons, to increase, and this is of course a gratifying indication that the relative number of those living beyond middle age is increasing. Contagious diseases naturally show large fluctuations, but scarlet fever appears to have decidedly decreased, the number of deaths per thousand having fallen from 12 to 7.

We reproduce diagrams originally

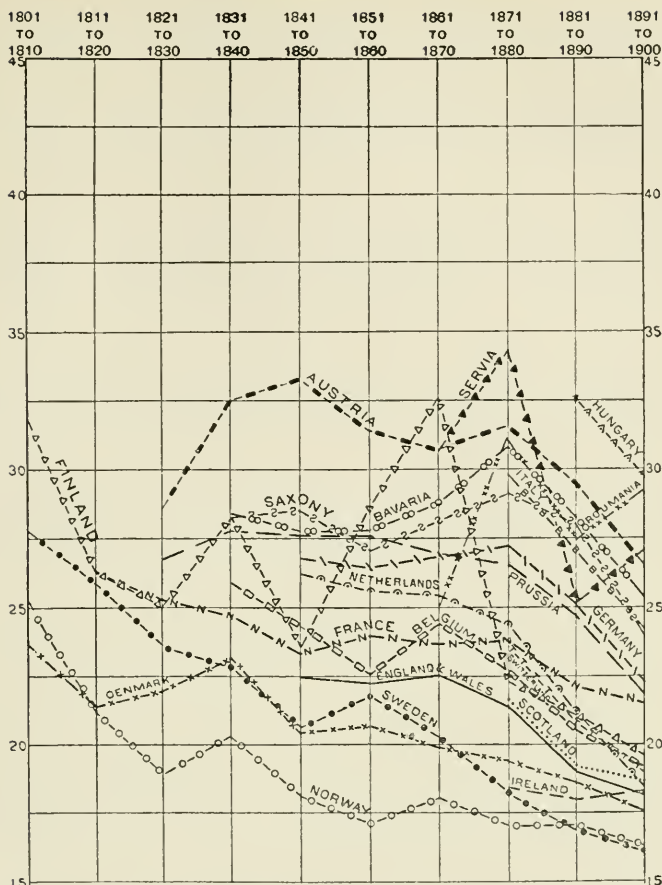


AVERAGE ANNUAL BIRTH RATES OF CERTAIN EUROPEAN COUNTRIES PER 1,000 OF POPULATION, BY DECADES (STILLBIRTHS EXCLUDED).

prepared under the auspices of the French government showing graphically the average annual number of births and deaths per thousand of population in those countries which publish adequate statistics. It will be noted that in all parts of the civilized world both the birth rates and the death rates tend to decrease, and that, as a rule, those countries having the lowest death rates have also the lowest birth rates. As is well known, the lowest birth rate is that of the French—22.2 during the decade 1891 to 1900 and still falling. This is followed very closely by the figures for Ireland—23.

There is then a break to Sweden and Switzerland, with birth rates, respectively, of 27.2 and 28.1. The highest birth rates recorded are in Serbia and Roumania. Germany has a birth rate of 36.1; England and Wales of 29.9. During the last twenty years the birth rate has fallen in every country and the death rate has also fallen in practically all countries. The lowest death rates, 16.1 and 16.3, respectively, are in Sweden and Norway. The highest, 33.4 and 30, respectively, are in Russia and Spain.

It should be remembered that the birth rate and the death rate have



AVERAGE ANNUAL DEATH RATES OF CERTAIN EUROPEAN COUNTRIES PER 1,000 OF POPULATION, BY DECADES (STILLBIRTHS EXCLUDED).

probably decreased even more rapidly than the statistics show, as births and deaths, as a rule, tend to be more accurately recorded now than formerly. Thus it is by no means certain that the birth rate in England increased from the period 1841-50 to 1871-80. Even now when an infant dies at an early age, the registration of both birth and death is sometimes not recorded, and this custom was doubtless formerly more prevalent than it is at present.

THE GROWTH OF THE STATE UNIVERSITIES

THE first bulletin of the Carnegie Foundation, which is concerned with

the admission of the officers of state universities to retiring allowances, contains a good deal of interesting information in regard to the growth of these institutions, part of which is summarized in the accompanying table. The first column gives the date of founding, and some may be surprised to find that the first state universities were established in the south, Michigan, often looked upon as the oldest state university, being in fact the tenth in order. Another circumstance perhaps not generally known is the fact that two state universities were established in Ohio at the early dates of 1804 and 1824, and that the Ohio State

University	Date of Founding	No. in Faculty	No. in Instruction	Student Registration		Annual Tuition		Annual Receipts		Approximate Total Gifts from State and Gen'l Gov't Since Founding	Approximate Total Gifts from Private Citizens Since Founding	Academics Standard
				College Students	Total Enrollment	For Residents of State	For Non-residents of State	1896	1906			
Georgia	1785	23	35	157	408	None	50.00	27,614	82,642	240,000	142,500	11
North Carolina	1789	36	74	482	870	30.00	30.00	25,000	235,600	705,000	705,273	11.6
Tennessee	1794	27	105	283	695	86.00	86.00	61,410	88,390	1,877,250	43,896	10
South Carolina	1801	19	28	151	296	58.00	58.00	25,000	41,730	2,556,000	None	5.2
Ohio (Athens)	1804	22	49	389	1272	15.00	15.00	27,670	135,198	600,000	31,000	12
Indiana	1820	49	109	1684	1684	None	None	114,684	252,138	2,500,000	100,000	15
Miami	1824	36	43	261	991	15.00	15.00	18,341	97,472	1,038,400	50,000	14
Virginia	1825	35	80	.....	706	40.00	115.00	70,801	111,094	1,710,000	1,627,195	8.4
Alabama	1831	17	43	249	491	27.00	87.00	29,625	56,053	No record	No record	10
Michigan	1837	113	332	3772	4136	30.00	40.00	227,707	451,697	6,407,003	817,851	14
Missouri	1840	85	179	1541	2072	5.00	5.00	127,709	306,111	3,211,797	294,000	15
Iowa	1847	53	150	1341	1815	20.00	20.00	101,554	432,304	3,525,666	52,750	15
Mississippi	1848	17	27	303	571	2.50	2.50	32,643	144,704	2,124,000	40,000	11
Wisconsin	1848	119	317	2443	3571	20.00	50.00	314,436	804,521	6,603,860	90,941	14
Utah	1850	30	92	203	1063	10.00	10.00	55,152	159,007	1,691,000	65,000	10.7
Louisiana	1860	27	38	311	458	None	60.00	36,525	65,214	1,252,245	43,308	9.5
Washington	1861	43	79	709	925	None	20.00	70,000	149,345	2,892,840	500,000	15
Kansas	1864	88	104	1348	1706	10.00	20.00	104,715	391,778	3,171,812	400,000	15
Maine	1867	28	64	540	687	60.00	70.00	29,900	41,900	581,718	155,000	13.5
West Virginia	1867	36	66	299	1422	12.00	62.00	27,248	138,660	1,159,221	75,000	12.5
California	1868	116	403	3897	4173	None	20.00	325,495	727,536	Data not available	Data not available	15
Illinois	1868	156	408	2792	4074	24.00	24.00	144,455	825,107	6,443,752	25,000	14
Minnesota	1868	90	3.7	2929	3955	20.00	40.00	199,221	345,261	5,359,208	191,000	15
Nebraska	1869	84	190	2122	2914	6.00	26.00	70,655	357,060	3,805,149	70,717	14
Ohio State (Columbus)	1870	92	151	.....	2157	18.00	18.00	112,784	628,000	4,881,063	281,285	14
Arkansas	1872	36	64	381	1528	None	None	120,400	143,900	1,760,000	None	10
Oregon	1876	19	79	369	506	15.00	15.00	37,200	117,200	890,824	50,000	15
Colorado	1877	31	115	700	1327	10.00	10.00	86,500	140,000	1,727,125	55,000	15
South Dakota	1882	24	44	180	381	5.50	5.50	20,000	68,750	No record	No record	15
North Dakota	1883	50	50	189	733	8.00	8.00	12,500	177,250	1,000,000	70,000	13
Texas	1883	43	119	1385	1991	10.00	10.00	123,413	289,193	3,792,307	150,000	11.4
Nevada	1886	23	27	143	254	None	None	37,250	130,000	429,839	85,000	12
Wyoming	1886	18	26	118	241	2.50	2.50	2,933	26,081	510,844	1,100	14
Idaho	1889	16	45	231	363	None	?	45,616	96,537	507,215	75,000	15
Arizona	1891	13	24	47	226	None	20.00	10,500	32,200	245,000	10,000	15
New Mexico	1891	8	19	28	89	6.00	40.00	11,500	29,615	272,021	14,182	15
Oklahoma	1892	19	29	203	475	None	None	Rec. des. by fire	85,000	.....	.....	15
Montana	1895	15	23	142	289	10.00	10.00	22,000	57,000	368,710	None	14
Florida	1904	14	14	70	136	10.00	30.00	.....	57,710	170,000	40,000	9.9

University at Columbus was not established until 1870. The University of Florida, established in 1904, makes the number of state universities thirty-nine, and, as there are three in Ohio, the number of states and territories having state universities is thirty-seven.

Nearly all the universities of the eastern states have at one time or another received appropriations from the state and have been to a certain extent under state control, and at present certain universities, such as Pennsylvania and Cornell, may be regarded as partly state institutions. In each case the governor of the state is a member of the board of trustees and appropriations are made by the state for the support of the university.

The next column of the table gives the numbers of instructors and students, according to which the University of New Mexico, with 89 students and nineteen instructors, is the smallest of the institutions, while the largest are Wisconsin, with 3,571 students and 317 instructors; Minnesota, with 3,955 students and 317 instructors; Illinois, with 4,074 students and 408 instructors; Michigan, with 4,136 students and 332 instructors, and California, with 4,173 students and 403 instructors. According to the figures annually compiled by Professor Tombo and published in *Science*, the five largest universities which are independent of the state are Harvard, with 5,343 students and 583 instructors; Chicago, with 4,731 students and 341 instructors; Columbia, with 4,650 students and 600 instructors; Cornell, with 4,075 students and 525 instructors; and Pennsylvania, with 3,934 students and 375 instructors. It will thus be seen that the leading corporations do not differ greatly in size.

The table next gives the annual tuition fees, whence it appears that Indiana, Arkansas, Nevada and Oklahoma charge no fees, while in a number of other states the fees are nominal. Sev-

eral of the universities charge higher fees to non-residents than to residents of the state. Perhaps the most interesting data on the table are the comparisons of the annual income apart from tuition fees of these universities in 1896 and 1906. There is here an increase that holds for every institution without exception and which is certainly most remarkable. Thus the annual income of the ten principle universities of the middle west was in 1896 \$1,689,200, whereas ten years later it was \$4,577,700. The figures given in the table are, however, somewhat obscured by the fact that there is no distinction made between appropriations for current income and for new buildings. The two following columns give the approximate total appropriations from the state and gifts from private sources, showing clearly how largely state universities are dependent on the public for support. Thus Illinois, which has received \$6,000,000 from the state, has only received \$25,000 by private gift. Some of the universities, as Michigan and California, have, however, received considerable gifts. In his report President Pritchett urges that the universities must depend either on public appropriations or on private gifts, and this point of view is on the whole supported by these figures and by conditions in foreign countries. The conditions, however, are not necessarily final. In New York City, for example, there are admirable museums of natural history and of the fine arts and botanical and zoological gardens which are supported almost equally by the city and by private gifts.

SCIENTIFIC ITEMS

WE regret to record the deaths of Major James Carroll, U. S. A., known for his researches on yellow fever, and of Professor W. O. Atwater, of Wesleyan University, known for his researches on nutrition.

AN institution for the suppression of tuberculosis is planned in Germany in honor of the twenty-fifth anniversary of the discovery of tuberculosis by Professor Robert Koch. Appeal is made for contributions sufficient to make the institution a tribute of gratitude to Koch, similar to those with which the name of Pasteur has been honored in France and that of Lister in England.—A “Morley Chemical Laboratory,” named in honor of Dr. Edward W. Morley, emeritus professor

of chemistry, will be built at Western Reserve University during the present year.

PROFESSOR A. N. SKINNER, of the U. S. Naval Observatory, has retired on reaching the age limit of 62 years.—Dr. Ellwood Mead, chief of irrigation investigation of the U. S. Department of Agriculture and professor of irrigation in the University of California, has accepted the office of chief of irrigation investigations for Australia.

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NOTES ON ASIATIC MUSEUMS

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ASIA, whatever its contributions to art and science, has, humanely speaking, taught little to the west as to either the means of forming its illustrative collections or the manner of displaying them; in fact, as far as I am aware, the trend of Asiatic culture has been rather to deter its people from collecting. For such an interest, to pure eastern ideals, would foster the heresy that the things of this world are to be the more highly prized: or, in another direction, it might suggest undesirable ostentation. It is from the latter point of view, in fact, that a Japanese collector will still decline to exhibit his treasures outside of the circle of his intimate friends. In any event, whatever be the reasons, I think it may safely be said that comprehensive collections were early unknown in the east. In India, land of fabulous riches, the pre-European collections appear to have been confined to the cabinets of rulers and the wealthiest civilians, and were made up largely of decorated objects, ivories, jewels, arms, now and then menageries—the last sometimes including exotic animals. Such collections were usually little more than a gathering of valuable heirlooms, objects obtained during travels, and curiosities generally.¹ And similar conditions prevailed, as far as I was able to find, in China. In Japan, small collections were, and are, very numerous. Professor Morse, knowing his theme more accurately than Huish, describes the Japanese as a nation of collectors; but such collections, as I think all will agree, are notable for their quality rather than their comprehensiveness, and are formed in the

¹ I recall, as a typical specimen in such an early collection a copy in ivory of a human skeleton which a rajah (of Tanjore) had caused to be prepared in Paris—for a genuine one could not, according to the rules of caste, be used in his anatomical inquiries.

strictest sense for private use. In Japan, as elsewhere in Asia prior to the invasion of European methods, there was not, I believe, a single public museum, unless indeed we regard as museums the storehouses of temples. These, however, contained little more than the reserve stock from which objects for temple service or decoration were chosen.

The earliest Asiatic museum appears to have been established in the Moluccas, about half a century after their definite settlement by the Dutch, and in the classic work² of Georgius Everhardus Rumphius, written at the close of the seventeenth century, we have a record of the number and variety of objects which had been gathered together by this enterprising collector in the room of curiosities in Amboyna (*Amboinsche Rariteitkamer*). It is evident that this collection was well represented in mollusks, crustaceans and echinoderms. It contained a number of minerals and a small collection of fossils, the latter representing many groups. The descriptive catalogue of Rumphius, it may be mentioned, is well known to naturalists as containing the first account of the soft parts of the chambered nautilus, accompanied, too, by a figure which for a century and a half proved the most accurate in existence. Few details appear as to the organization of this pioneer Asiatic museum. Its founder was a well-to-do merchant in Amboyna, and it was probably installed in one of his warehouses. As far as I am aware, there is no proof that it was formally opened, in the sense of a modern museum, but by analogy of contemporary collections it is probable that the curiosity room of Amboyna was as freely open to visitors as the similar collections in London, Dresden or Paris.

In India the modern public museum found its definite foothold at the time of the extension of British rule. At the end of the eighteenth century, there were already active collectors among the officials of the East India Company, but in general the material then collected, whether ethnological, plant or animal, found its way into Europe. In the work of Linnæus, for example, we find record of many Indian species which had been sent him by European collectors. It was by such early workers in various Indian cities that societies were formed which became of considerable importance toward the middle of the nineteenth century. And it is to these local societies that the origin of many of the recent museums is due.

In the present paper it is not my plan to refer even in outline to all museums of Asia. Those of Japan are so important that they might conveniently be reserved for a separate paper. The Dutch museums, moreover, I have not had an opportunity of visiting, nor yet those on the continent in the Malayan states. When in Calcutta, I

² Amsterdam, François Halma, 1705. Part of the collection, as Mr. C. Davies Sherborn has kindly ascertained for me, was later sent to Europe and sold, 1682, to Cosmo de Medici III. It was subsequently transferred to Austria as part of the Medicæan inheritance.

was told by Dr. Annandale of the interesting museum at Kuala Lumpur in Selangor, the federal capital of the Malayan states, which promises to be most complete. A building is here in process of construction, which will make this museum twice the size, for example, of the well-known museum at Colombo. Its present curator is the ornithologist, Mr. H. C. Robinson, formerly of Liverpool. I learned also of the museum at Thai Ping, capital of Perak, which contains a remarkable ethnological cabinet and an extensive collection of Malayan reptiles. This museum, under the direction of Mr. Leonard Wray, is, I was told, one of the most interesting in Asia. The museum at Bangkok, on the other hand, is less important, in spite of the apparently more favorable conditions under which it has grown up. And its arrangement leaves much to be desired.

Of the museums in the Dutch East Indies, that at Batavia is easily the first, containing extensive local collections, both ethnological and faunistic. A second museum, at Trevandrum on the west coast of Java, has received the favorable comment of experts. Its collection of whales is especially complete.

The museums in China may be dismissed with but few words. In the Chinese treaty-ports there is little interest in museum matters on the part of resident Europeans, whose ways are commercial, and under existing conditions the Chinese authorities can hardly be expected to grant funds for such purposes. The best Chinese museum is the one at Hong Kong. It has a separate building with well-lighted galleries, and exhibits a fairly extensive series of natural history and ethnological objects, coins, etc. It is clear, however, that its resources are very restricted, and such a museum, whatever its effect upon the oriental visitor, is apt to be uninspiring. In Peking, however, in connection with the Imperial University of China, an important museum will soon be opened; it may be mentioned that this branch of the governmental educational work has been largely directed by the Japanese.

The museums of the following cities may be given a more detailed report, *viz.*, Singapore, Colombo, Madras, Calcutta, Lahore and Jaipur. The museum in Bombay is said to be uninteresting, and I neglected to visit it.

SINGAPORE

The museum at Singapore, known as the "Raffles Museum," had its origin (1844) as a proprietary library in which local curiosities came to be preserved. In 1874 the institution was taken over by the British government (Straits Settlements), and in 1887 the present building was provided to house a collection acquired at the time of the Victorian Jubilee. The building is well proportioned, suitably lighted and planned, Fig. 1, but too small for its needs, and the authorities are now constructing an addition. This will be of the same size as the



FIG. 1. SINGAPORE. THE RAFFLES MUSEUM AND LIBRARY.

earlier building, and is to be connected with it by a wide gallery passing from behind the main staircase. Each building measures about 250 feet long by 50 feet wide; the cost of both buildings amounts to about \$100,000. Building, it will be seen, is distinctly less expensive than in the Occident!

The site of the museum is in a small city park. Entering the building from the town side, one passes into a spacious rotunda well filled with cases, and giving one the preliminary color of the local fauna. Prominent, for example, is a tiger fairly well mounted, and with a jungly background. This huge creature had been, I was told, the household pet of a local Rajah. One may mention, incidentally, that the tiger is decidedly on the increase in the Malay Peninsula, indeed even in the immediate neighborhood of Singapore. The collection of insects in the museum is important. In the rotunda is a series of native beetles and orthopters, including among the former, wonderful longicorns and Scarabæids; and, among the orthopters, the best examples I have seen of leaf insects and walkingsticks. At one side of the rotunda is the entrance of the Raffles Library (now grown to 30,000 volumes), which is devoted largely to works dealing with local natural history and ethnology. At the back of the rotunda, one ascends the stairs and enters the natural-history gallery and the ethnological rooms. Among noteworthy exhibits I recall the collection of local butterflies and moths, and a series, possibly the best extant, of paradise birds. The reptiles include turtles, crocodiles, and a great number of local snakes. The cases containing the gibbon and

ourang would. I am sure, be cordially envied by the best western museums, even though the mounting is not quite up to the present standard. I recall particularly one male ourang with a splendid head, and of extraordinary size. Among the zoological rarities are the relics of a very young dugong. This had been brought to the museum living and the preparations are accompanied by sketches of the living animal. In invertebrate material there is the usual range of crustacea, corals and sponges, most of them carefully determined. The ethnological cabinet (Malayan) is important, as one might expect, and its arrangement is well carried out. There are models of houses, some with inao suspended about them, suggesting primitive Japanese buildings, even with the curious "frog-thigh beams" crossing at the ridge pole, as in the most primitive Shinto temples, and with these are many suggestions of relationship with Japan. Of Dyak objects there are rich gatherings, including a collection of krisses, costumes, ornaments, etc. There are a number of the sharply-perforated carvings still used to decorate Urala ceremonial feasts, groups of objects used in marriage ceremonies, collections illustrating local basket-making, an art in which the Malayans are especially skillful. There are also cases of native cloths, coins and ornaments of gold and silver, the latter not as good in quality as one might reasonably expect. In the artistic treatment of many of these objects there are obvious affinities with the South Seas. Much of the success of the present museum has been due to the labors during the past dozen years of the director, Dr. R. Hanitsch, whose picture, as he stands in front of his bungalow, near



FIG. 2. SINGAPORE. BUNGALOW OF THE MUSEUM-DIRECTOR, DR. HANITSCH.

the museum garden, is shown in Fig. 2. Dr. Hanitsch is a graduate of the University of Jena, and was for many years demonstrator in zoology in the University College of Liverpool. The former director was the well-known ornithologist, Mr. W. Davidson.

COLOMBO

This museum, oldest in its building (1877) and in some regards best of Asiatic museums, was built on the outskirts of the city in the middle of the old cinnamon gardens. It is especially important to the general visitor as giving him the only practicable glimpse of the antiquities of Ceylon. It stands back from the red road, its buff-colored and long two-storied façade appearing prominently against a setting of tropical trees. On the ground floor are arranged the antiquities: in one room are objects in precious metals and stones, arm-rings, necklaces, utensils, caskets, sword handles, and near by are figures dressed in Cingalese finery of early times; on another side is a library containing Ceylonica, and a mass of the ruler-shaped books with palm-leaf pages scratched with Sanscrit; on still another side, in an imposing gallery, is a collection of architectural and decorative objects in wood and stone, including the colossal lion brought from Pollonarna, on whose back the native kings sat when they administered justice. Here also is the beautiful window from the ruin of Yapahoo, and a huge portrait statue of a twelfth-century king. On the walls of the main staircase are copies of the frescoes of the caverns of Sigiri. The collection of antiquities extends even into the garden, where several of the larger statues and a shrine are exhibited. The upper story of the museum is devoted to natural history, and here the distinguished director, Dr. Arthur Willey, has arranged groups of animals to give the visitor an adequate picture of the wild life of Ceylon. Alcoholic and dried specimens are well displayed and labeled, and even living specimens are interspersed, as in a case containing leaf-resembling insects. Dr. Willey has taken greatly to heart the need of exhibiting living creatures in the interest of his museum and, in the garden adjoining his office, he has arranged a small menagerie, which has proved a great attraction no less to foreign visitors than to natives. Nor does Dr. Willey escape his living charges even when he goes to his bungalow, for there I saw a fine series of the rare lemur, *Loris*, as well also as a specimen of *Ichthyophis glutinosa*, the earthworm-like amphibian whose development was studied by the Sarazins.

No one should leave Ceylon before paying a visit to the renowned botanical gardens, with a small museum, at Peradeniya: for it is but seventy miles from Colombo and at a delightful altitude (1,500 feet). For here within a small area one may see, with a minimum of discomfort, the rarest and most striking tropical plants, from minute orchids

to banyan trees: and one wanders about as in a land of enchantment, amid traveler's palms, which will spout water if one punctures a stalk, breadfruit, cocoanuts, nutmegs, cinnamon, deadly upas trees, *Bauhinia racemosa*, with its cable-like stems, and the telegraph-plant, *Desmodium gyrans*, automatically lifting and dropping its leaves. Incidentally, too, there are zoological interests. Not uncommon are trees infested with flying foxes: and in the neighborhood the traveler to the east may see his first elephant working in the fields, but willing to show his paces for a few pice; so too one might happen to make the acquaintance of land-leeches, which find their way unpleasantly through the



1. 3. COLOMBO. CITY MUSEUM.

. But as an offset to this he may see a wild
r. Or he may discover a cobra and induce it

MADRAS

dras is in many regards a quite modern in-
are new and spacious, built of dark brick and
ecenic style. Fig. 4. Its collections illustrate
istory, archeology and art of southern India.
is the important Connemara library, rich in
history of Madras. The natural-history section
seum, part of its collection dating from 1846,
nterest of including within its animal galleries
mens. The archeological section is rich in pre-
lly pottery: it contains, however, many objects
enteenth centuries, arms, armor and cannon, of
s well as of native wars. Among other curious

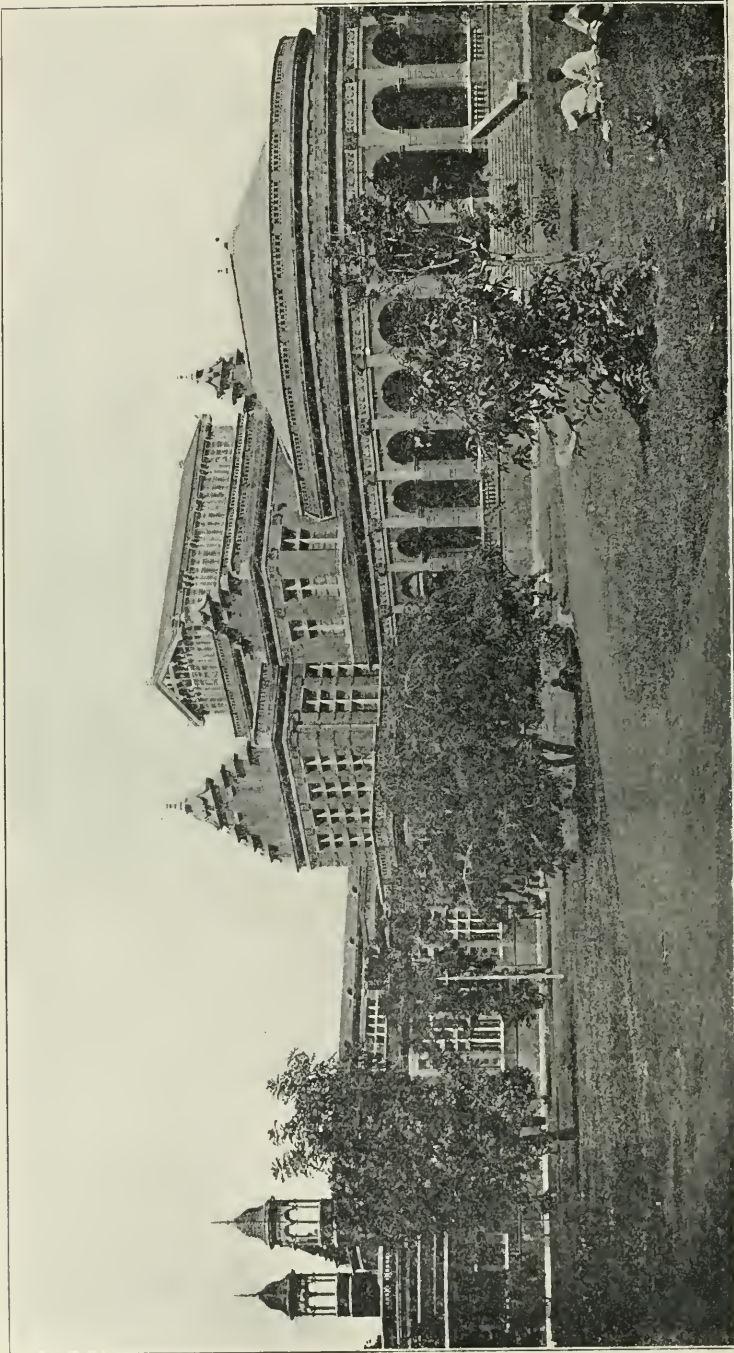


FIG. 1. MADRAS. MUSEUM BUILDING.



FIG. 5. MADRAS. VIEW IN ONE OF THE NATURAL HISTORY GALLERIES.



FIG. 6. MADRAS. GALLERY OF METAL WORK.

relics is a large swinging-post terminating in an elephant head, probably unique, which in a remote village was used up to relatively recent times for human sacrifices. The art objects are represented in great variety and are attractively exhibited, textiles, pottery, wood and metal work, musical instruments, drawings. One recalls especially the suite of pictured cotton curtains for which Madras has long been noted; also the beautiful repoussé work in precious metals (Fig. 6). The museum is distinctly one of the most successful in India. Its director is the zoologist, Dr. Edgar Thurston.

CALCUTTA

The museum of Calcutta is far and away the most imposing of Asiatic museums, representing, as it does, the government of India in the imperial capital. Its buildings, Fig. 7, are the most extensive and its collections the most important. In this region, moreover, it is the oldest, for it preserves the collections of the Asiatic Society of Bengal, founded in 1784.

The success of the museum, it may be remarked, has been due in no small degree to its tradition of selecting directors eminent both as scientists and as executives. It was to Mr. Bly, an early curator of the Asiatic society (1842 to 1862), a voluminous correspondent of Darwin, by the way, that the credit belongs for securing governmental assistance in erecting the museum's first building. His successor was John Anderson, who remained in charge until 1886. And his, in turn, was Dr. Wood Mason, 1886 to 1893. And from that time to the present, the director has been Major A. Alcock, widely known for his researches on the deep-sea fauna of the Bay of Bengal.



FIG. 7. CALCUTTA. THE INDIAN MUSEUM. Front view. From Chowringhee.



FIG. 8. CALCUTTA. HALL OF INDIAN MAMMALS.

At the time of the opening of the new museum (about 1890) the collections of the Asiatic Society were transferred to the British government. They comprised principally three classes of objects, zoological, ethnological and archeological, the last of unique importance. They include the antiquities secured by Colonel Mackenzie from the Amravati tope (1796 and 1816), and the collections of the Tytlers, Kittoe and General Cunningham. The last named investigator, one of the founders of the museum, secured for it also the objects from the Bharhut stupa. The entire collection thus contains in large measure the figured specimens in Indian archeology and it is especially rich in the finds from the neighborhood of Lucknow, Nagpore, Benares and Delhi. The ethnological cabinet is based upon the collection of Roer, whose catalogue dates from 1843. By 1882 no less than 600 crania were listed. The zoological division of the museum is based upon the Blyth collection of the Asiatic Society. As early as 1862 there were represented 600 species of mammals, 2,000 species of birds, 300 of reptiles, and 1,000 of mollusks: and since this time the zoological collection has increased vastly. Figs. 8, 9, 10.

The Calcutta museum expanded notably about two decades ago, when it incorporated two allied institutions. The first of these was the economic museum of the government of Bengal (added in 1887), whose collections are arranged in separate galleries, and the second, the collections of the geological survey, these added (about 1890) when the public museum was opened. The subsidy for the latter institutions, it may be mentioned, is separate from that of the main museum, about 40,000 rupees a year being granted by the government for their annual support. And a similar appropriation is made for the remainder of the museum.



FIG. 9. CALCUTTA. PORTION OF THE BIRD HALL.

Upon the relation of politics and science in India, that the well-known gallery of fishes arranged by the director, after years of labor, has recently been demolished by order of the Viceroy, Lord Curzon, who could find in Calcutta no other gallery in which to house a collection of relics of the Sepoy rebellion!

The invertebrate collections of the museum are extensive and well displayed. Particularly interesting is the entomological cabinet which includes the de Nicéville lepidoptera and the Dugeon hymenoptera, the latter comprising about 1,000 type specimens. The entomological survey undertaken by the museum is its last development, establishing in 1903 the first entomological laboratory in India, in connection with a commission of forestry. Equally important are the geological materials exhibited in the museum. Of meteors, no less than 400 falls are represented. Of ores there are many varieties, especially in manganese. In fossils there is valuable Cretaceous material, including the types of Blanford; among late acquisitions there is a wonderful specimen of *Elephas antiquus (namadicus)*. The fossil mammals from the Sewalik Hills near Simla are also preserved in the

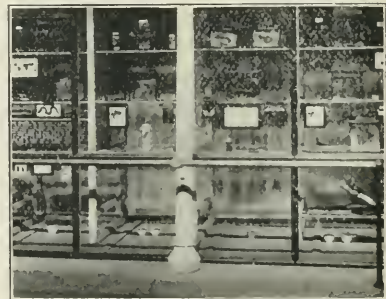


FIG. 10. CALCUTTA. A CASE IN THE REPTILE GALLERY.

gallery of paleontology, but they fail to impress a visitor who has seen the associated remains of late Tertiary mammals in other museums.

LAHORE

The museum at Lahore is known to most foreigners as the "wonder-house" of Kipling, and in front of its door stands the ancient cannon with its memories of Kim and his lama. Although intended to represent the natural sciences as well as the arts, this museum need hardly be referred to in the former regard, for its specimens are few and poorly displayed. In its materials for the study of art, however, it ranks among the foremost in the east. Its predecessor was a school of arts, founded as a memorial to the Viceroy, Lord Mayo, and carried out during the early seventies, under its first principal and curator, Mr. J. Lockwood Kipling (1875-92). The development of the present museum then came about as a result of the Victorian jubilee. A general subscription secured the necessary funds, and the corner-stone of the present building (Fig. 11) was laid by Prince Victor in February, 1890, and its collections were opened to the public two years later. The design was furnished by Mr. Lockwood Kipling in cooperation with the Indian architect Bryam Singh.

As in the majority of the Indian museums, the native style has been as closely followed as museum needs would permit, and the tall galleries and massive doorways (Fig. 14) leave pleasant impressions in the



FIG. 11. LAHORE. THE MUSEUM.



FIG. 12. LAHORE. THE HALL OF GRÆCO-BACTRIAN SCULPTURE.

visitor's mind. The exhibit space includes about 28,000 square feet and the galleries are 45 feet high. As already noted, the museum is interesting in its art exhibits, especially in its Græco-Bactrian sculptures, for these, as is well known, played a most important part in the early art of northern India. This collection, occupying a special gallery 100 feet in length (Figs. 12 and 13), was brought together in the northwest provinces during the early seventies, and is unique. To be mentioned also are the collections of carved wood, musical instruments, Hindu portraits, including a series of the Singh, Hindu drawings, many Afghan documents, and technical exhibits decidedly modern in museum technique, illustrating, for example, the arts of the Punjab, glass making, lac turning, leather work, etc. In connection with these there are models of local industries cleverly carried out in terra-cotta by native artists. One may mention also a remarkable series of Madras curtains elaborately stamped with religious ceremonies and personages. The present administration of the art school and museum is in the hands of Mr. Percy Brown, artist and archeologist, well known for his studies on Græco-Bactrian art. The museum is now affiliated with the Asiatic Society of Bengal, with the Geological Survey of India and with the Forestry Commission. As an echo of Indian social conditions one hears that the museum has been opened one day a month for Hindu women, women attendants then taking charge of the galleries. The museum is popular, and the attendance averages over 1,000 a day.

FIG. 13. LAHORE. DETAIL IN HALL OF SCULPTURE.



FIG. 13. LAHORE. DETAIL IN HALL OF SCULPTURE.



FIG. 14. LAHORE. THE HALL OF NATIVE ARTS.

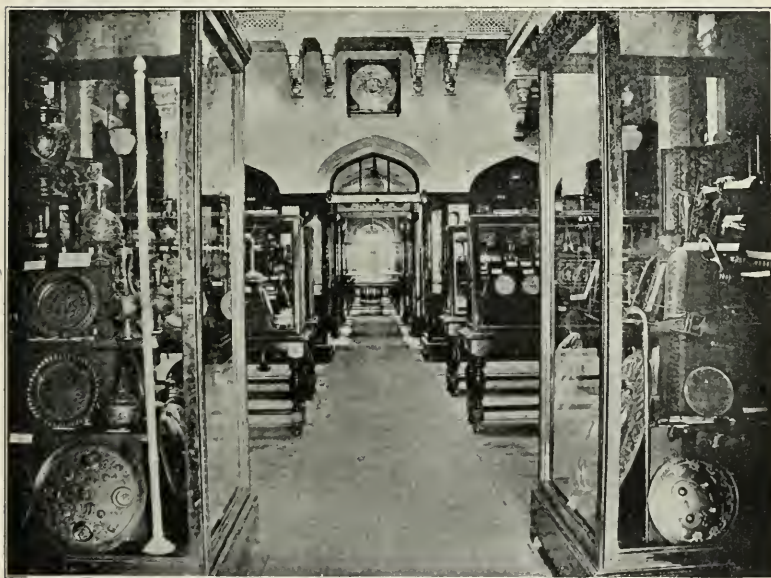


FIG. 15. JAIPUR. HALL OF METAL WORK.

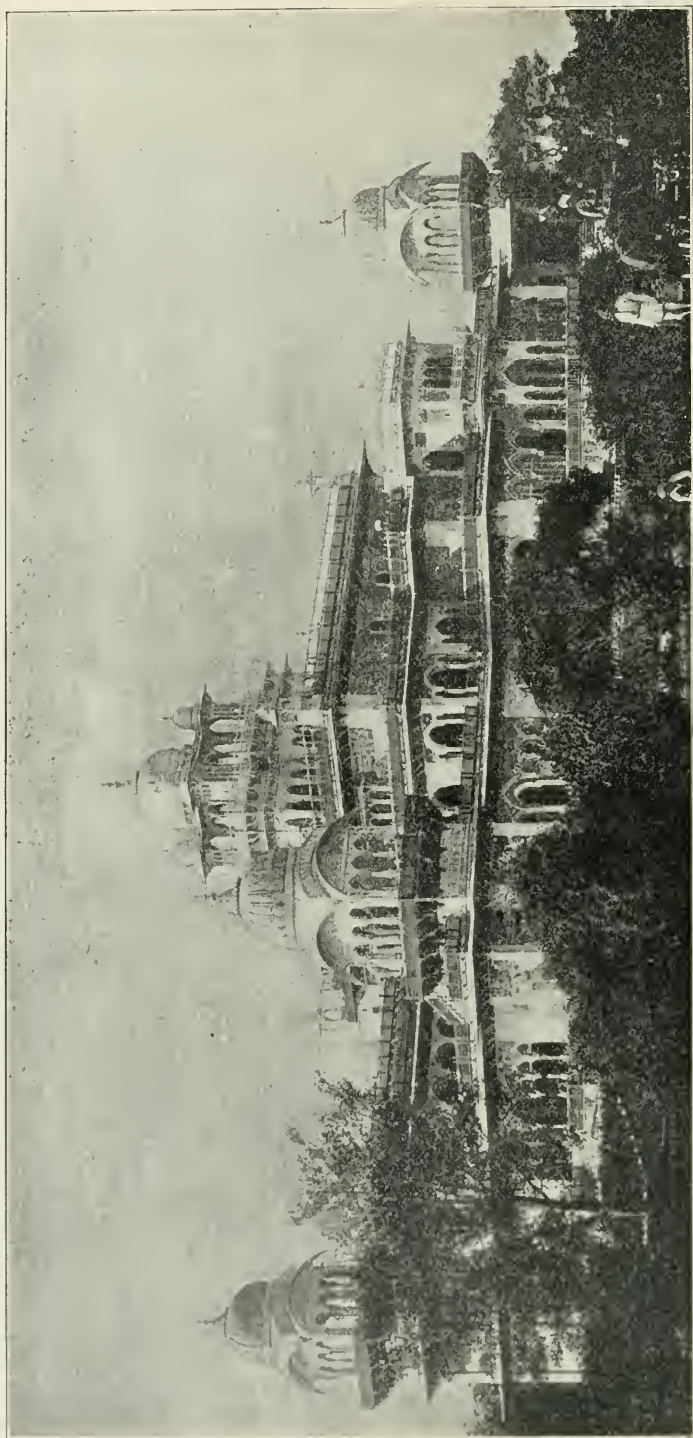


FIG. 16. JAIPUR. THE MUSEUM.

JAIPUR

Jaipur may be mentioned, finally, as furnishing the best type of a museum supported by a native prince—in the present case by the reigning maharajah, Sir Sawdi Madho Singh. It is an imposing monument to this ruler's modernness, and it has already borne interesting fruit in developing and bettering the many art-industries of Jaipur.

The building is by no means a small one—at least two hundred feet in length. It stands in the public gardens, an elaborate structure in Indo-Saracenic style, with shaded balconies and corridors, and with numerous courtyards cooled by plants and fountains, Fig. 16. Its scientific collection is small, limited to models and specimens of minor interest. But in modern and semi-modern art objects, in metal, stone, wood or textile, the present museum is, I believe, unsurpassed. Especially beautiful are the examples of metal work, Fig. 15, many of which are the family treasures of the maharajah—gun-metal and silver bidri work, damaskeens from Kashmir, silver repoussé from Trichinopoly and Ceylon, articulated objects in silver from Bengal, silver figures from Mathura, enamels in gold from Jaipur, in silver from Multan, brasses numberless, and a bewildering series of jewelry from all parts of India. Nowhere can one receive a more illuminating impression of the decorative possibilities in native art. An excellent reference, by the way, is the beautifully illustrated handbook of the museum prepared by its honorary secretary, Colonel Hendley (1895).

THE PLACE OF LINNÆUS IN THE HISTORY
OF SCIENCE¹

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THE recent celebrations of the bicentenary of Linnæus's birth had one sort of appropriateness in somewhat higher degree than is usual in such commemorations: they helped pay the debt of posterity to one of the great figures of the history of science in the currency that he had especially valued. For Linnæus had very markedly the last infirmity of noble mind. *Famam extendere factis* was his chosen device, which he often prints, with a pride justified only by the event, upon the title-pages of his books; and his biographers are at one in emphasizing the intensity of his desire for fame. It was, indeed, the solid and enduring fame of the productive scholar that he sought, not the applause of the groundlings; his ambition was to link his name to some lasting and imposing part of the ever-enlarging fabric of organized knowledge, and thereby to take rank among the acknowledged masters of those who know. That this ambition, large as it was, has been more than fulfilled, is sufficiently evidenced by the world-wide commemoration of this anniversary of his birth—even in cities of the western continent which were themselves non-existent when he came into the world. No naturalist of his century, and few naturalists of any period, have so universal a popular reputation, or are, by so nearly common consent, given a place among the immortals not far removed from Copernicus, Galileo, Descartes, Leibniz and Newton—to mention only his predecessors. Yet, when seriously scrutinized, Linnæus's position in the history of science is a peculiar one. With his name there is commonly associated no epoch-making hypothesis, not a single important discovery, not one fundamental law or generalization, in any branch of science. The forty years of his active life constitute a period prolific in fruitful hypotheses and signalized by the original enunciation of a number of valid generalizations of the first order of importance; of none of these was he the author. To go no farther than the biological sciences which Linnæus professed: Before 1750, Daubenton and Buffon had begun to establish the new science of comparative anatomy and were making known the striking homologies which run through the structure of all species of vertebrates; between

¹ Revision of a paper read before the Academy of Science of St. Louis at its celebration of the two hundredth anniversary of the birth of Linnæus.

1745 and 1751 Maupertuis had promulgated, and defended with effective arguments, the theory of the transformation of species; in physiology, the significant fact of the independent irritability of muscle was discovered by Haller in 1757; in embryology, the doctrine of epigenesis was revived and finally established by Caspar Friedrich Wolff in 1759. As for the science of botany, the foundations had been laid, and the general outlines and principles which were to continue to rule during Linnæus's time had been established by the end of the preceding century. The founder of modern scientific botany is Cesalpino (1583). In microscopic plant anatomy and histology, the investigations and descriptions which were to underlie the science for something like a century had been made before Linnæus's birth by Grew, Malpighi, Leeuwenhoek. In plant physiology, the rôle of the sap had been studied by Malpighi, and the fundamental facts made clear by Hales in his "Vegetable Statics," 1727; the function of pollen in the fecundation of seeds had been shown by Camerarius before the end of the seventeenth century; the existence of the sexual distinction in plants had been insisted upon by a long succession of botanists, English, German, Italian and French; and during Linnæus's lifetime the physiological rôle of leaves was being made clear (so far as the condition of chemistry at the time permitted) by the philosopher Christian Wolff² and by Bonnet.³

Not only is all this true, but it is also a fact that Linnæus has been not absolutely unfairly represented, by one of the historians of modern science, as an obstacle to the scientific progress of his time. President White, in his "Warfare of Science and Theology," after speaking of certain anticipations of nineteenth century conceptions by DeMaillet, Robinet and Bonnet, remarks:

In the second half of the eighteenth century a great barrier was thrown across this current—the authority of Linnæus. . . . The atmosphere in which he lived and moved and had his being was saturated with biblical theology, and this permeated all his thinking.

Yet, though in the intellectual movement of his time Linnæus was an extreme conservative, if not something of an obscurantist; though he was far surpassed by several of his contemporaries in that kind of insight and constructive power which leads to the discovery of the great general laws of nature; and though the heavy pioneer work even in his favorite science had been done before his time by the great investigators of the end of the seventeenth century—though all this is the case, none of these others equals Linnæus in popular repute or in accepted standing in the history of science. I can not say that I think this altogether just, though if it be less than just, the proper inference

² "Entdeckung der wahren Ursache von der Vermehrung des Getreydes," 1718. Cf. also his "Vernünftige Gedanken von dem Gebrauche der Theile in Menschen, Thieren und Pflanzen," 1725, Pt. II., chap. 5.

³ "Récherches sur l'usage des feuilles," 1754.

is not that we should praise Linnæus less, but some of the others more. I have, however, mentioned these things, not for the sake of measuring out Linnæus's glory with a hopeless attempt at exact distributive justice, but for the sake of defining more precisely, and in terms of explicit contrast—which is the only illuminating way of defining—the nature and limits of Linnæus's contribution to the evolution of the sciences. He was the one naturalist of first eminence whose work lay entirely, or almost entirely, within the sphere of descriptive and classificatory science. His rôle is precisely described by the term which he himself employed; he was not the originator of, nor a great discoverer in, botany, but he was the "reformer" of that science, *reformator botanices*, and in a less degree, of zoology. And in using this term to describe his work, the emphasis should be upon the "form." He was, in other words, an unsurpassed organizer, both of scientific material and of scientific research; he introduced form and order, clearness and precision, simple definitions and plain delimitations of boundaries, into sciences previously more or less chaotic or confused or impeded with cumbrous and inappropriate categories and terminology.

This reformation was the result of the three improvements effectually introduced by Linnæus and indissolubly associated with his name. The first, which seemed the most impressive and did most to establish his fame among his contemporaries and for several generations thereafter, was really the least permanent and the least valuable of his contributions: this was the introduction of a new artificial system of classification, based, in the botanical field, upon the differences of the sexual organs of plants. The second was the introduction of the binomial nomenclature, the system of so-called "trivial" names, which put a final end to the hopeless length and complexity of botanical and zoological specific names, and sharply differentiated the naming of organisms from the description of them. The third and, I suppose, the most useful as well as most durable of all of Linnæus's improvements, was the establishment of a new descriptive terminology in botany, the drawing up of a set of terms, each with clearly defined meaning, for designating concisely the distinguishable parts and organs of plants, and the several types of form of which each part is susceptible. By these means Linnæus imposed order and harmony upon a realm that had hitherto suffered much from anarchy; he gave a common language to those who tilled its fields, and provided them with working tools of an unprecedented simplicity and convenience. And where he thus introduced order he also, as a natural consequence, introduced abundance. Both directly and indirectly Linnæus immensely augmented the store of concrete botanical information. The science thus simplified and systematized and given a convenient means of expression became vastly more attractive and interesting; in particular,

it came to be a field in which many minds, of all orders of ability, could do useful work, and could make their work dovetail into the work of others in such wise that each was conscious of having contributed a definite part to an immense and impressive edifice of an intelligible outline and design. Alike by the superior convenience of his classification, nomenclature and terminology, by the force and serious enthusiasm of his personality, and by the example of his admirably exact observation, Linnæus stimulated a prodigious amount of ardent and careful botanical and zoological research on the part of others. His own pupils went out, literally by the score, not only over Europe, but to the uttermost parts of the earth, to collect new species and study geographical distribution. A number of these young enthusiasts, whose names are honorably recorded by one of Linnæus's biographers, lost their lives in these expeditions. The eight volumes of Linnæus's "*Amœnitates Academicæ*" contain 186 dissertations by almost as many of his pupils, the subject and treatment being in nearly every case suggested, and the results corrected, by Linnæus himself; most of these contain contributions of valuable—and many contain what were in their day highly original—botanical, zoological or mineralogical data. Nor was the effect of Linnæus's simplification and systematization of botany limited to the setting of other and younger men of science to work. His efforts also notably increased the general vogue of botany, as a result of which it long enjoyed an exceptional popularity and an unusual amplitude of endowment among the sciences.

This aspect of Linnæus's work is effectively presented—all the more effectively for a considerable touch of rhetorical exaggeration—by Magdeleine de Saint-Agy in his continuation of Cuvier's "*Histoire des Sciences Naturelles*" (1845); the passage illustrates so well, if not precisely, what Linnæus did, at least what he had the credit of doing, that I venture to translate it.

The influence of Linnæus, says this historian, was not limited to the investigations and voyages which he caused to be made; in imitation of him, similar voyages and investigations were ordered made by several states. Sweden, being a small and poor country, had no great means for multiplying such expeditions; but England, France and Russia had them carried out in great numbers; and Linnæus during the last years of his life had the pleasure, as Condorcet puts it, of seeing nature interrogated on all sides in his name. There was no class of people—even to princes—who did not busy themselves with natural history, and above all with botany—since this science presents none of the difficulties of anatomy and since the method of Linnæus is of a simplicity which renders it accessible to everybody . . . Botany thus became universally familiar. Those who were fond of gardening multiplied the varieties of their plants, since they could now know the names of them without being Latin scholars, and since gardeners could now understand one another when referring to the plants they cultivated. All gardens, both botanical and pleasure gardens, were filled with a multitude of plants which rich folk had brought at great expense from foreign

lands. The taste for botany dominated all minds; kings became botanists, properly so called, and were desirous of having their own botanical gardens. Louis XV. had the garden of Trianon; George III., that of Kew; Francis I., emperor of Austria, that of Schoenbrunn. These three princes were useful to the science by their gardens and by the emulation which they occasioned; but it is after all, to the happy discovery of a dual nomenclature that these advances were primarily due. From the moment when common names were to be had, corresponding in all parts of the globe, collections were zealously made; museums were enriched; and it was not difficult to multiply researches, now that the science was within everybody's reach. . . . Such is the prodigious impulsion that Linnæus gave to the science of natural history.

Yet it is important, in the interest of historical truth, to point out that even in these things which constitute his peculiar work—specifically, in his reformation in taxonomy, nomenclature and terminology—Linnæus was in no respect a pioneer or an originator. It was his good fortune to be able to develop and carry through suggestions and outlines of procedure which had been made by his seventeenth-century precursors, and to exploit to the utmost an abundant legacy of botanical knowledge, methodological ideas, and botanical interest which had come down to his generation. Nothing, indeed, could be farther from the truth than the notion which appears to have wide popular currency, that there was little botanical study or knowledge worth mentioning before Linnæus. It is, on the contrary, eminently a case where *vixerunt fortes ante Agamemnona*. Any who suppose sixteenth and seventeenth century botany to be a negligible quantity will find it instructive to examine the shelves of the library of the Paris Jardin des Plantes; or to remember that Jean Bauhin's "Historia universalis plantarum" (1660), consisting of forty books, contained descriptions of some 5,000 plants, with 3,500 figures, and cost the equivalent of about \$18,000 to produce—or that, a little later, Ray's "Historia plantarum generalis" gave a classified arrangement and description of 11,700 plants.⁴ And while Linnæus assuredly gave, as has been said, a great impulsion to the popular and fashionable interest in botany and zoology, it was an interest which was extremely well developed before his time—which, in fact, made his own work and his own contemporary fame possible. It was not through his influence first that states and monarchs learned the propriety of establishing botanical gardens. The Jardin royal du Louvre, for example, was established by Henri IV. in 1590, and the Jardin des Plantes was founded in 1626. By the middle of the seventeenth century both public and private gardens, often with scientific establishments connected with them, were becoming fairly common. And, as I have said, the particular reforms through which chiefly Linnæus achieved his results were essentially not discoveries nor innovations of his own. It will be profitable to note

⁴ These figures are taken from Hoefler's "Histoire de la Botanique," 1872.

briefly the earlier history of the ideas involved in each of these three reforms.

First, then, concerning classification. Linnæus's great precursors in this field were Cesalpino,⁵ Ray and Tournefort. Cesalpino was a sixteenth-century enthusiast of the revival of the Peripatetic philosophy; and it was largely the influence of a fresh study of Aristotle's logic and metaphysics which led him to condemn all the then customary ways of classifying and naming plants—by their medicinal or other practical properties, the localities in which they are found, and the like—as being based upon mere "*accidentia*," and to insist upon the necessity of an orderly arrangement by genera and species founded upon the presence of common visible characters.⁶ In his selection of the characters by reference to which the primary division into genera is to be made, he is guided by considerations drawn from the Peripatetic metaphysics. The essential character of any "substance" consists in its "end" or "function" (*opus*). The distinctive function of the vegetative soul is twofold, nutrition and "the generating of its own like"; the latter is the higher, and it also presents more numerous and sensible points of variation in different plants. It follows that plants should be divided into genera according to the differences in form and arrangement of their "fruit-producing" organs (*ex modo fructificandi, ex propriis quae fructificationis gratia data sunt*). With this as a starting-point, Cesalpino proceeds to a series of successive divisions in which 840 species find place. Ray's contributions to taxonomy had less success and influence than those of Cesalpino and of Tournefort, and are therefore historically less significant; but concerning their intrinsic merit it is worth while quoting the recently expressed opinion of a living botanist of high authority, who places Ray⁷ as a taxonomist above Linnæus himself. It was the English naturalist, says M. Bonnier,⁸ who must be regarded as "the true founder of the natural method"; "he it was who first enunciated the essential principles on which the classification of plants ought to be founded, who made clear the difference between phanerogams and cryptogams, who discovered the distinction between monocotyledons and dicotyledons, who established in a rational manner the main divisions of the vegetable kingdom."

⁵ 1519-1603. Cesalpino was a physician to Pope Clement VIII., and professor of *materia medica* and director of the botanical garden at Pisa. He was the original discoverer of the circulation of the blood; the doubts which have been sometimes expressed whether he anticipated Harvey's conception in its fullness have been shown to involve the overlooking of an explicit passage in Cesalpino's "De Plantis" (1583): cf. Du Petit-Thouars in "Biographie Universelle," s. v.

⁶ "De Plantis" (1583), *Lib. I.*, Cap. XIII.

⁷ "Historia Plantarum," 1686.

⁸ "Le monde végétal," 1907, pp. 48-9.

At a natural method Tournefort made no more attempt than did Linnæus. But of the principles and purposes of a good artificial classification he had an entirely clear comprehension; and of such a classification of then known plants he gave an elaborate and imposing exemplification. Of what a "natural system" would be, if one could attain to it, Tournefort, like his Swedish successor, had a conception rather mystical or theological than scientific; it would be an arrangement of animals and plants according to the "natural" or "essential" species established by "the Author of Nature." But for his actual scheme⁹ he recognizes plainly that the primary criteria are the practical ones of simplicity and convenience. A genus or species, for botanical purposes, is "simply the whole group of plants that have a character in common which essentially distinguishes them from all others"; and in the selection of the characters by means of which the division is to be made we may ignore metaphysical considerations. Tournefort observes (apparently reflecting upon Cesalpino): "Let no one say that, since the sole end of nature is the production of fruit, we ought to consider the fruit as the noblest part of the plant. The intentions of nature are not in question here, nor yet the nobility of the several parts; what concerns us is to find means of distinguishing different kinds of plants with the greatest possible clearness. If the least of their parts served this purpose better than those which are called the noblest, it would be necessary to prefer the former." Tournefort's actual classification, based upon the characters of both flowers and fruit, realized these ideals of serviceableness, convenience and consistency somewhat imperfectly. But it was the ruling one in the science for nearly half a century; and, accompanied as it was by careful descriptions of an immense number of species, it furnished a model upon which Linnæus needed only to improve.

The Swedish naturalist's simplification of nomenclature was not only approximated, but actually anticipated, by at least one of his predecessors. As Professor Underwood has pointed out, the binomial system of naming plants was used by Cornut in his "*Canadensis Plantarum Historia*" as early as 1635.¹⁰ Later Tournefort, a botanist of greater eminence and influence, though he followed this example only partially, insisted emphatically upon the need for a reform and simplification of nomenclature. So far as the names of genera are concerned, he observes that "one ought to make a very great difference between naming plants and describing them"; he remarks that "nothing is so unfavorable to the reformation of botany as the habit which

⁹ "Elemens de la Botanique," 1694; the Latin version of this, "Institutiones Rei Herbariæ," with some alterations, appeared in 1700.

¹⁰ Underwood in *Torreyia*, October, 1903, and in *POPULAR SCIENCE MONTHLY*, June, 1907. A brief and often binomial nomenclature is ascribed by Bonnier to Belon (*d.* 1574), whose work I have not seen.

has come to prevail of judging of the nature of plants from the etymology of their names," and recommends that generic names be formed exclusively "out of words that have of themselves no meaning"; and he ridicules the long descriptive names then used by many botanists.¹¹ The designations of species, however, he considers, should consist of the name of the genus *plus* a clear descriptive indication of the differentia of the species; and since the latter can not always be expressed by a single word, Tournefort does not employ a uniformly binomial nomenclature. But from the reforms already recommended and adopted by the great botanist of the preceding generation to the Linnæan system of "trivial" specific names, the step was easy and obvious.

Again, in providing botany with an appropriate set of terms for the concise indication of the parts and organs of plants, Linnæus was merely following the suggestion and extending the work of another great seventeenth-century reformer in science. It was Joachim Jung¹²—a naturalist whose intellectual force so impressed his contemporaries that Leibniz did not hesitate to compare him to Aristotle, or Comenius to liken him to Euclid—who was the father of comparative morphology in botany, who introduced into the study of the characters of plants real thoroughness and precision, who insisted upon the need for a system of clear, unambiguous organographic terms, and who himself devised and introduced a number of the terms still in use. His "*Isagoge Phytoscopica*" (1622) was wholly devoted to urging and exemplifying this reform; all the principal parts of plants are distinguished and defined with admirable clearness, their possible variations of form noted, and new and explicit names for these variations proposed. Jung seems,¹³ for example, to have been the first to employ the terms petiole or pedicule and perianth; to classify the arrangements of leaflets as digitate and pinnate, and to subdivide the latter sort into paripinnate and imparipinnate; to speak of the disposition of leaves as opposed, alternate, triangulate, etc. The descriptive terminology of botany has, of course, since expanded immensely; but the credit for the origination of the language of that science must unquestionably be assigned to Jung and not to Linnæus.

It still remains true, however, that Linnæus united these three reforms in a single system; that he carried each of them farther than had any of his predecessors; and that by the force of his personality he was able to gain for them a general acceptance which they had hitherto lacked. Though we must, therefore, make some deduction

¹¹ "*Elemens de Botanique*," 1694, pp. 14, 36, 38.

¹² Born in Lübeck, 1587, died at Hamburg, 1657. He published comparatively little, and his principal botanical works were brought out by friends after his death.

¹³ The assertion that Jung was not anticipated in the use of these terms rests upon the authority of Hoefler, "*Hist. de la Botanique*."

from the current view of the originality of Linnæus's work as reformer and organizer of botanical knowledge, we need not on that account greatly lower our estimate of its actual importance in the history of science. And yet we must, to get a just picture, always remember the character, as well as the magnitude, of that work; we must remember that it was, all but exclusively, form, system, nomenclature and specific observations that Linnæus contributed to the biological sciences, rather than fundamental discoveries, pregnant hypotheses or illuminating general ideas. Even in the presence of the impressive picture of the solid results of Linnæus's life-work drawn by the French historian of these sciences, one can not help recalling a caustic remark—which I have already elsewhere cited—of Linnæus's contemporary, Maupertuis, then president of the Berlin Academy of Sciences. Maupertuis spoke of zoology; but we may generalize his observation: "All these treatises on plants and animals which we as yet have," he says (about 1750), "are—even the most methodical of them—no better than pictures pretty to look at; in order to make of natural history a veritable science, naturalists must apply themselves to researches which can make us acquainted not simply with the form of this or that organism, but with the general *processes* of nature in the production of organisms and the conservation of them." Towards making natural history a veritable science in this sense Linnæus did relatively little; but it is not quite true to say that he did nothing at all. Towards the discovery or the establishment of two generalized laws respecting the processes of nature in the production and the perpetuation of vegetal organisms Linnæus made some contribution; and of these something ought briefly to be said, the more because they are often neglected in the accounts of Linnæus's work.

1. Although, as has been remarked, the fact of sexuality in plants had been noted by a number of great naturalists before 1718, the doctrine was not, in Linnæus's youth, at all generally accepted. It was possible at the beginning of the eighteenth century for a botanist so eminent as Tournefort to combat and ridicule the idea; and for the Imperial Academy of Sciences of St. Petersburg, so late as 1759, to offer a prize for the best argument either *for or against* the doctrine of sex in vegetables. Linnæus gave the weight of his authority, as well as of some new experimental evidence, to the affirmative of this question. By him the fact may be said to have been finally established; and by his sexual system of classification the idea was made a familiar and fundamental common-place of even popular botanical knowledge.

2. By his doctrine of the "Prolepsis Plantarum" and "Metamorphosis Plantarum"—which one of his disciples declared to be "the most subtle discovery of any which can be put forward by the investigators of nature in our age," but which there lacks space to set forth

in its details—Linnæus began that theoretical reduction of the several parts of a plant to modifications, under special conditions, of a few simple organs, which Goethe was to elaborate and carry much farther in his “*Metamorphose der Pflanzen*” (1790). Goethe makes due acknowledgment of his debt to Linnæus (who was his constant study in his early years¹⁴) in that treatise, the place of which in the history of botany is well known. Contemporary botanists would, I suppose, incline to question whether this theory has done greater service or harm to the progress of their science. Its chief value lay in its tendency to suggest the idea of the unity of type—and eventually the idea of the common derivation through processes of transformation—of different species. Both of these ideas were far from the mind of Linnæus; with him the theory took the form only of the purely specific doctrine of the interchangeability of leaf and flower under varying conditions of nourishment, or at different phases of the individual plant’s growth.

In these two instances, then, Linnæus made some contribution to the unification, as well as to the augmentation, of knowledge. Yet his lack of any penetrating insight into the larger relations of biological facts and the absence in him of any sound grasp of scientific method, disqualified him from taking a place among those who have materially enriched our stock of the ideas and categories which may be used in the interpretation of nature. His emphasis upon the static aspects of the world of living organisms—upon the fixed characters of species—and upon the descriptive rather than explanatory business of scientific inquiry made his influence, on the whole, an obstacle to the development and diffusion of those evolutionary ideas which were already stirring in a number of minds of his generation. His ineptitude in the more philosophic part of the naturalist’s work could not be better shown than in the one treatise in which he attempts a broad philosophical view and a wide correlation of organic phenomena. This writing, “*Œconomia Naturæ*,” which was greatly admired by his contemporaries, points out in how diverse and complicated ways organisms of different species interact with one another, and are reciprocally adapted to one another, as well as to the conditions of survival in their environment. In dilating upon this Linnæus may be said to call attention, more than a century before Darwin, to the reality and importance in nature of the struggle for existence between species; for he shows how every kind of organism has its natural enemies, with which it keeps up

¹⁴ The poet himself wrote in his “*Geschichte meines botanischen Studiums*” (1817): “After Shakespeare and Spinoza, it was Linnæus who had the greatest influence upon me—chiefly, indeed, by the opposition that he provoked. For when I strove to make my own his sharp, clear-cut divisions and his apt and serviceable but often arbitrary laws, an inner conflict arose in me: what he sought forcibly to hold apart, the deepest need of my nature made me wish to bring back to unity.”

an unceasing warfare or competition, as a result of which the otherwise excessive multiplication of each kind is prevented and the equilibrium of nature is preserved. But all these just observations lead Linnæus to nothing more useful to science than the *quam pulchre!* We are invited to see in the arrangement whereby the lion saves the lamb from the Malthusian inconvenience of over-multiplication simply an evidence of design in nature. It never occurs to the great naturalist to consider that, as Maupertuis put it, "since only those creatures *could* survive in whose organization a certain degree of adaptation was present, there is nothing extraordinary in the fact that such adaptation is found in all the species that now exist." Looking upon the same general class of facts as those which were to be considered by Wallace and Darwin, Linnæus finds in them nothing but the occasion for the wholesale introduction of teleological considerations, in place of causal explanations. In setting the example of such a proceeding, Linnæus certainly did much to hold biology back from its proper methods and its proper problems. In this, as in his general failure to take a philosophic view of his subject, his mental attitude was peculiarly uncongenial to the greatest intellect—if not the greatest botanist—of those whom he largely influenced. Goethe kept up a lifelong protest against all purely descriptive science and all introduction of teleological notions into the explanation of natural phenomena. And it is from Goethe in his old age that I may, in closing, quote a somewhat severe, but not unilluminating, remark upon the master of the poet's early botanical studies;¹⁵ since it contains a sort of philosophical pun, it is necessary to give it in the German:

Eine zwar niedere doch schon ideelle Unternehmung des Menschen, ist das Zählen, wodurch im gemeinen Leben so vieles verrichtet wird; die grosse Bequemlichkeit jedoch, die allgemeine Fasslichkeit und Erreichbarkeit giebt dem Ordnen auch in den Wissenschaften Eingang und Beifall. Das Linnésche System erlangte eben durch diese Gemeinheit seine Allgemeinheit; doch widerstrebe es einer höheren Einsicht mehr, als dass es solche förderte.

Yet if Linnæus was not qualified to lead biology into the promised land of that "higher insight"—if he even somewhat delayed its progress thither—it must still be said that he left all the sciences with which he dealt incomparably better provisioned for that progress than they would have been without his work. He left to them an intensified ardor for the scrutiny of all the phenomena of nature, a better command of their own materials, and a greatly enriched and better ordered store of those concrete facts out of which, in time, scientific generalizations often almost spontaneously develop, and by which they must always eventually be tested.

¹⁵ "Aphoristisches," Weimar-Ausg., Teil II., Bd. 6, § 356 (1829); cited by Wasielewski in his "Goethe und die Descendenzlehre."

THE PROBLEM OF AGE, GROWTH AND DEATH

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VI. THE FOUR LAWS OF AGE

Ladies and Gentlemen: I have referred in these lectures repeatedly to the cell and its two component parts, the nucleus and the protoplasm. To-night I shall have only a few references to make directly to these, and shall pass on for the latter part of the hour to another class of considerations bearing upon the problem of age. Before we turn to these new considerations, however, I wish to say a few words by way of recapitulation concerning the changes in the cells as corresponding to age. Cells, as you know from what I have told you, undergo in the body for the greater part a progressive change which we call their differentiation. We may say that there are four kinds of cells for purposes of an elementary classification to be used in a simple exposition like the present. The first kind are those cells of the young type, in which the protoplasm is simple, and shows as yet no trace of differentiation. These cells are capable of rapid multiplication, and some of them are found still persisting in various parts of the adult body, and serve to maintain the growth of the body in its mature stage. Another class of cells presents to us the curious spectacle of a partial differentiation; such are the muscle fibers by which we accomplish our voluntary movements. These fibers consisted originally only of protoplasm with the appropriate nuclei, but, as they are differentiated, part of the protoplasm changes into contractile substance. Another part remains pure protoplasm unaltered. If now the muscular or contractile portion of the fiber be destroyed, the undifferentiated part of the protoplasm then shows that it has still the power of growth. It has only been held back by the condition of organization, and we see in the regeneration of these fibers evidence of the fact that so long as the protoplasm is undifferentiated it has the power of growth, which, however, does not reveal itself unless an opportunity is afforded. Third, we come to the cells which are moderately differentiated; such, for instance, are the cells of the liver, and, if for any reason a portion of the liver be injured by accident or disease, we find that these partially differentiated cells reveal at once that they have a limited power of growth still left. If we pass on to the fourth class, that in which differentiation is carried to the highest extreme, we find that the cells do not have the power of multiplication. Such are the

nerve cells by which the higher functions of the body are carried on. They represent the extreme of cellular differentiation, and almost never do we see these cells multiplying after the differentiation is accomplished. Presented in this form, we then recognize, it seems to me clearly, the effect of differentiation upon the growth of cells. The facts are clear as to their meaning.

We can, however, proceed a little farther than this, because we can actually determine, approximately at least, the rate at which cells multiply, and that we can do by means of determining the mitotic index. The mitotic index is the number of cells to be found at any given moment in the active process of division out of a total of one thousand cells.

May I pause a moment to recall this picture to you and ask you to notice at this point the curious darker spot which represents a nucleus



FIG. 61. PORTION OF THE OUTER WALL OF A PRIMITIVE MUSCULAR SEGMENT OF A CAT EMBRYO OF 4.6 MM. Harvard Embryological Collection Series 398, section 115. The resting nuclei are oval, pale and granular. The dividing or mitotic nuclei, of which there are three, are dark, irregular in outline and show the chromosomes. In this case the dividing nuclei all lie near the inner surface of the wall. The picture illustrates the ease with which mitotic figures may be recognized.

in process of division? You will see it would be easy in such a preparation as this to count the nuclei one by one until one had got up to a thousand, and to record, as one went along, how many of the nuclei are in process of division, for the nucleus in division is easily recognized. This process of division is named mitosis: the figure which the nucleus presents while it is undergoing division we call a mitotic figure. Counting the dividing nuclei, we may determine that in a thousand cells there are a given number which have nuclei in process of division, and such a number I propose to call "the mitotic index." I wish now only to call to you attention this picture because it enables me to illustrate before you the method of measuring the mitotic index.

In the rabbit embryo at seven and one half days, I have found by actual count that there are in the outer layer of cells, known technically as the ectoderm, 18 of these divisions per thousand. In the middle layer, technically the mesoderm, 17, and in the inner layer, the endoderm, 18. At ten days we find the number already reduced, and the figures are, respectively, 14, 13 and 15, and for the cells of the blood only 10. There has already been a great reduction. In the next phase of development (rabbit embryo of thirteen days), we find, however, that the parts are growing irregularly, some faster, some slower. We note that wherever a trace of differentiation has occurred, the rate of growth is diminished: where that differentiation does not show itself, the

rate of growth may even increase in order to acquire a certain special development of a particular part. So that instead of uniformity of values for the mitotic index, we get a great variety. But, nevertheless, the general decline can be demonstrated by the figures. In the spinal cord the index is 11, in the general connective tissue of the body 10; for the cells of the liver 11; in the outside layer of the skin 10; in the excretory organ 6; in the tissue which forms the center of the limb also 6. There has, then, been a rapid decline in the rate of cell multiplication just in this period when differentiation is going on. This is, so far as I know, an entirely new line of research. The counting of a thousand cells is not a thing to be done very rapidly; it must be undertaken with patience, care, and requires time. It has not, I regret to say, been possible for me yet to extend the number of these counts beyond those I have given you, but it is easy to say that in the yet more differentiated state, the number of cells in division is constantly lessened, and it is only a question of counting to determine the mitotic index accurately. That there is a further diminution beyond that which the mitotic indices I have demonstrated to you represent is perfectly certain. I only regret that I am not able to give you exact numerical values.

I wish very much that my time permitted me to branch off into certain topics intimately associated with the general theme we have been considering together on these successive evenings, but we can only allude to a few of these. The first collateral subject on which I wish to speak to you briefly is that which we call the law of genetic restriction, which means that after a cell has progressed and is differentiated a certain distance, its fate is by so much determined. It may from that pass on, turn in one direction or another, always progressing, going onward in its cytomorphosis; but the general direction has been prescribed, and the possibilities of that cell as it progresses in its development become more and more restricted. For instance, the cells which are set apart to form the central nervous system after they are so set apart can not form any other kind of tissue. After the nervous system is separated in the progress of development from the rest of the body, its cells may become either nerve cells proper or supporting cells (neuroglia), which latter never acquire the nervous character proper, but serve to uphold and keep in place the true nervous elements. They represent the skeleton of the central nervous system. After the cells of the nervous system are separated into these two fundamental classes they can not change. A cell forming a part of the supporting framework of the brain can not become a nerve cell; and a nerve cell can not become a supporting cell. The destiny of them becomes more and more fixed, their future possibilities more and more limited, as their cytomorphosis goes on.

The law of genetic restriction has a very important bearing upon questions of disease. When disease occurs, the cells of the body offer

to us two kinds of spectacles. Sometimes we see that the cells causing the diseased condition are more or less of the sort which naturally belong in the body; that they are present where they do not belong, or they are present where they ought to be, but in excessive quantity. There is a kind of tumor which we call a bony tumor. It consists of bone cells such as are naturally present in the body, but that which makes this growth of bone a tumor is its abnormal dimensions, or perhaps its being altogether in the wrong place. The second sort of pathological alteration, which I had in mind, is that in which the cells really change their character. Now, the young cells are those which can change most; in which the genetic restriction has least come into play; and accordingly we find that a large number of dangerous, morbid growths, tumors, arise from cells of the young type, and these cells, having an extreme power of multiplication, grow rapidly, and they may assume a special character of their own; their genetic restriction has not gone so far that all their possibilities of change in the way of differentiation have been fixed; there is a certain range of possibilities still open to them, and they may turn in one direction or the other. Hence there may be pathological growths of a character not normally present in the body. It seems to me, so far as my knowledge of this subject enables me to judge, to be true that all such pathological growths depend upon the presence of comparatively young and undifferentiated cells being turned into a new direction. The problem of normal development and of abnormal structure is one and the same. Both the embryologist and the anatomist, on the one hand, and the pathologist and the clinician on the other, deal ever with these questions of differentiation, and practically with no others. All that occurs in the body is the result of various differentiations, and whether we call the state of that body normal or pathological matters little; still the cause of it is the differentiation of the parts.

The second of the collateral topics which I should like briefly to allude to is another branch of the study of senescence. The fact was first emphasized by the late Professor Alpheus Hyatt that in many animals there exist parts formed in an early stage and thereafter never lost. The chambered nautilus is an animal of this kind. The innermost chamber represents the youngest shell of the nautilus, and as its age increases, it forms a new chamber in its shell, and so yet more and more until the coil is complete. When we examine a shell of that kind we see permanently before us the various stages, both young and old, as recorded in shell formation. And so too in the sea-urchin, and in many of the common shell-fish, we find the double record, of youth and old age, preserved permanently. This has made it possible for Professor Hyatt and for Professor Robert T. Jackson, who has adopted a similar guiding principle, to bring a great deal of new light into the study of animal changes, and to attack the solution of problems which

without the aid of this senescent interpretation, if I may so term it, would be utterly impossible. This is an enticing subject, and I wish I had both time and competency to dwell upon it. But it is aside, as you see, from the main inquiries with which we have been occupied, for our inquiries concern chiefly the effect of cell-change upon the properties of the body, and the correlation of cell-change with age.

A natural branch of our topic is, however, that of longevity, the duration of life. Concerning this, we have very little that is scientifically satisfactory that we can present. We know, of course, as a fundamental principle, that every animal must live long enough to reproduce its kind. Did that not occur, the species would of course become extinct, and the mere fact that the species is existing proves, of course, this simple fact—that life has lasted long enough for the parents to produce offspring. The consideration of this fact has led certain naturalists to the supposition that reproduction is the cause of their termination of life; but it is not, it seems to me, at all to be so interpreted. We know, in a general way, that large animals live longer than small ones. The elephant is longer lived than the horse, the horse than the mouse, the whale than the fish, the fish than the insect, and so on through innumerable other instances. At first this seems a promising clue, but if we think a moment longer we recognize quickly the fact that a parrot, which is much smaller than a dog, may live one hundred years, whereas a dog is very old at twenty. There are insects which live for many years, like the seventeen-year locusts, and others which live but a single year or a fraction even of one year, and yet the long-lived and the short-lived may be of the same size. It is evident, therefore, that size is not in itself properly a measure of the length of life. Another supposition, which at first sounds very attractive, is that which explains the duration of life by the rate of wear, of the using up, of the wearing out, of the body. This theory has been particularly put forward by Professor Weismann, who in his writings calls it the *Abnutzungstheorie*—the theory of the wearing out of the body. But the body does not really wear out in that sense. It goes on performing the functions for a long time, and after each function is performed the body is restored, and we do not find at death that the parts have worn out. But, as we have seen, we do find at death that there has been an extensive cytomorphosis, cell-change, and that the living material, after having acquired its differentiation, passes now in one part, now in another, then in a third, to a yet further stage, that of degeneration, and the result of degeneration, or atrophy, as the case may be, is that the living protoplasm loses its living quality and becomes dead material, and necessarily the functional activity ceases. We must, it seems to me, conclude that longevity, the duration of life, depends upon the rate of cytomorphosis. If that cytomorphosis is

rapid, the fatal condition is reached soon; if it is slow, the fatal condition is postponed. And cytomorphosis in various species and kinds of animals must proceed at different rates and at different speeds at different ages. Birds grow up rapidly during their period of development; the cell change occurs at a high speed, far higher than that which occurs in man, probably, during his period of development. But after the bird has acquired its mature development, it goes on almost upon a level for a long time; the bird which becomes mature in a single year may live for a hundred or even more. There can be during these hundred years but a very slow rate of change. But in a mammal, a dog or a cat, creatures of about the same bulk as some large birds, we find that the early development is at a slower rate. The animals take a much longer period to pass through their infancy and reach their maturity, but after they have reached their maturity they do not sustain themselves so long. Their later cytomorphosis occurs at a higher speed than the bird's. This is a field of study which we can only recognize the existence of at present, and which needs to be explored before, to any general, or even to a special scientific, audience, any promising hypotheses can be presented. Definite conclusions are of course still more remote.

Next as regards death. The body begins its development from a single cell, the number of cells rapidly increase, and they go on and on increasing through many years. Their whole succession we may appropriately call a cycle. Each of our bodies represents a cell cycle. When we die, the cycle of cells gives out, and, as I have explained to you in a previous lecture, the death which occurs at the end of the natural period of life is the death which comes from the breaking down of some essential thing—some essential group of members of this cell cycle; and then the cycle is broken up. But the death is the result of changes which have been going on through the successive generations of cells making up this cycle. There are unicellular organisms; these also die; many of them, so far as we can now determine, never have any natural death, but there are probably others in which natural death may occur. It is evident that the death of a unicellular organism is comparable to the death of one cell in our own bodies. It is not properly comparable to the death of the whole body, to the ending-up of the cell cycle. Is there anything like a cell cycle among the lower organisms? among the protozoa, as the lowest animals are called? It has been maintained by a French investigator, by the name of Maupas, that such a cycle does exist, that even in these low organisms there is a cell which begins the development, and that gradually the loss in the power of cell multiplication goes on until the cycle gives out and has to be renewed by a rejuvenescent process, and this rejuvenating process he thinks he has found in the so-called conjugating act of these animals, in which there occurs a curious migration of the nucleus of

one individual into the cell body of another. Whether he is right or not remains still to be determined. You will recognize, I hope, from what I have said, that we have now some kind of measure of what constitutes old and young. We can observe the difference in the proportion of protoplasm and nucleus, the increase or diminution, as the case may be, of one or the other. If it be true that there is among protozoa, among unicellular animals, anything comparable to the gradual decline in the growth power which occurs in us, we shall expect it to be revealed in the condition of the cells—to see in those cells which are old an increase in the proportion of protoplasm, and consequently a diminution in the relative amount of nucleus. That subject is now being investigated, and we shall probably know, within a few years at least, something positive in this direction. At present we are reduced to posing our question. We must wait patiently for the answer.

The scientific man has many occasions for patience. He has to make his investigations rather where he can than where he would like to. Certain things are accessible to our instruments and methods of research at the present time, but other things are entirely hidden from us and inaccessible at the present. We are indeed, more perhaps than people in any other profession of life, the slaves of opportunity. We must do what we can in the way of research, not always that which we should like most to do. Perhaps a time will come when many of the questions connected with the problems of growing old, which we can now put, will be answered, because opportunities, which we have not now, will exist then. Scientific research offers to its devotees some of the purest delights which life can bring. The investigator is a creator. Where there was nothing he brings forth something. Out of the void and the dark, he creates knowledge, and the knowledge which he gathers is not a precious thing for himself alone, but rather a treasure which by being shared grows; if it is given away it loses nothing of its value to the first discoverer, but acquires a different value and a greater usefulness that it adds to the total resources of the world. The time will come, I hope, when it will be generally understood that the investigators and thinkers of the world are those upon whom the world chiefly depends. I should like, indeed, to live to a time when it will be universally recognized that the military man and the government-maker are types, which have survived from a previous condition of civilization, not ours; and when they will no longer be looked upon as the heroes of mankind. In that future time those persons who have really created our civilization will receive the recognition which is their due. Let these thoughts dwell long in your meditation, because it is a serious problem in all our civilization to-day how to secure due recognition of the value of thought and how to encourage it. I believe every word spoken in support of that great recognition which is due

to the power of thought is a good word and will help forward toward good results.

In all that I have said, you will recognize that I have spoken constantly of the condition of the living material. If it is in the young state it has one set of capacities. If it is differentiated, it has, according to the nature of its differentiation, other kinds of capacities. We can follow the changing structure with the microscope. We can gain some knowledge of it by our present chemical methods. Fragmentary as that knowledge is, nevertheless, it suffices to show to us that *the condition of the living material is essential and determines what the living material can do*. I should like to insist for a moment upon this conception, because it is directly contrary to a conception of living material which has been widely prevalent in recent years, much defended and popularly presented on many different occasions. The other theory, the one to which I can not subscribe, may perhaps be most conveniently designated by the term—the theory of life units. It is held by the defenders of this faith that the living substance contains particles, very small in size, to which the vital properties are especially attached. They look at a cell and find that it has water, or water containing a small amount of salts in solution, filling up spaces between the threads of protoplasm. Water is not alive. They see in the protoplasm granules of one sort and another, in plants chlorophyll, in animals perhaps fat or some other material. That is not living substance, and so they go striking out from their conception of the living material in the cell one after another of these component parts until they get down to something very small, which they regard as the life unit. I do not believe these life units exist. It seems to me that all these dead parts, as this theory terms them, are parts of the living cell. They are factors which enable the functions of life to go on. Other conditions are also there, and to no one of them does the quality of life properly attach itself. Of life units there is an appalling array. The most respectable of them, in my opinion, are the life units which were hypothetically created by Charles Darwin in his theory of pan-genesis. He assumed that there were small particles thrown off from different portions of the body circulating throughout the body, gathering sometimes in the germ cells. These particles he assumed to take up the qualities of the different parts of the body from which they emanated, and by gathering together in immense numbers in the germ cells they accomplished the hereditary transmission. We know now that this theory is not necessary, that it is not the correct theory. But at the time that Darwin promulgated it, it was a perfectly sound defensible theory, a theory which no one considering fairly the history of biological knowledge ought to criticize unfavorably. It was a fine mental achievement, but I should like also to add that of all the many theories of life units, this of Darwin's is the only one which seems to

me intellectually entirely respectable. Of supposed structural life units there is a great variety. Besides the gemmules of Darwin, there were the physiological units of Herbert Spencer. Professor Haeckel, the famous German writer, has special structural life units of his own which he terms plastidules; he gave them the charming alliterative title of perigenesis of the plastidules; the rhythm of it must appeal to you all, though the hypothesis had better be forgotten. Then came Nägeli, the great botanist, who spoke of the Idioplasma-Theilchen. Then Weisner, also a botanist, who spoke of the Plassomes. Our own Professor Whitman attributed to his life units certain other essential qualities and called them idiosomes. A German zoologist, Haacke, has called them gemmules. Another German writer, a Leipzig anatomist, Altmann, calls them granuli. Now these different life units, of which I have read you briefly the names, are not identical according to these authors. Everybody else's life units are wrong, falsely conceived, and endowed with qualities which they do not combine. There is a curious assemblage here of doxies, and each writer is orthodox and all the others are heterodox; and I find myself viewing them all from the standpoint of my doxy, that of the structural quality of the living matter, and, therefore, interpreting every one of these conceptions as heterodox, not sound doctrine, but something to be rejected, condemned and fought against. These theories of life units have filled up many books. Among the most ardent defenders of the theory of life units is Professor Weismann, whose theories of heredity many of you have heard discussed; though I doubt if many of you, unless you recall what I said previously, are aware of the fact that the essential part of Weismann's doctrine was the discovery of the theory of germinal continuity by Professor Nussbaum, whose name is seldom heard in these discussions. Weismann has gone much farther in the elaboration of the conception of life units than any of the other writers. He thinks the smallest of the life units are biophores. A group of biophores brought together constitutes another order of life units which he calls determinants; the determinants are again grouped and form ids; and the ids are again grouped and form idants. If you want to accept any theory of life units, I advise you to accept that of Weismann, for it offers a large range for the imagination, and has a much more formidable number of terms than any other.

I want to pass now to an utterly different line of study, the question of psychological development. If it be true that the development is most rapid at first, slower later, we should expect to find proof of that rate in the progress of mental development. In other words, we should expect to find that the baby developed faster than the child mentally, that the child developed faster than the young man, and the young man faster than the old. And do you not all instinctively feel immediately that the general assertion is true? In order, however, that

you may more fully appreciate what I believe to be the fact of mental development going on with diminishing rapidity, I should like to picture to you briefly some of the things which the child achieves during the first year of its life. When the child is born, it is undoubtedly supplied with a series of the indispensable physiological functions, all those which are concerned with the taking in and utilizing of food. The organs of digestion, assimilation, circulation and excretion are all functionally active at birth. The sense organs are also able to work. Sense of taste and of smell are doubtfully present. It is maintained that they are already active, but they do not show themselves except in response to very strong stimulation. Almost the only additional faculty which the child has is that of motion, but the motions of the new-born baby are perfectly irregular, accidental, purposeless, except the motions which are connected with the function of sucking, upon which the child depends for its nourishment. The instinct of sucking, the baby does have at birth. It might be described as almost the only equipment beyond the mere physiological working of its various organs. But at one month we find that this uninformed baby has made a series of important discoveries. It has learned that there are sensations, that they are interesting; it will attend to them. You all know how a baby of one month will stare; the eyes will be fastened upon some bright and interesting object. At the end of a month the baby shows evidences of having ideas and bringing them into correlation, association, as one more correctly expresses it, because already after one month, when held in the proper position in the arms, it shows that it expects to be fed. There is, then, already evidence and trace of memory. At two months much more has been achieved. The baby evidently learns to expect things. It expects to be fed at certain times; it has made the great discovery of the existence of time. And it has made the discovery of the existence of space, for it will follow, to some extent, the bright light; it will hold its head in a certain position to catch a sound apparently from one side; or to see in a certain direction. The sense of space and time in the baby's mind is, of course, very imperfect, doubtless, at this time, but those two non-stuff realities about which the metaphysicians discuss so much, the two realities of existence which are not material, the baby at this time has discovered. Perhaps, had some great and wonderfully endowed person existed who preserved the memory of his own psychological history, of his development during babyhood, we should have been spared the gigantic efforts of the metaphysicians to explain how the notions of space and time arose. Without knowing how, the baby has acquired them, and has already become a rudimentary metaphysician. We see, also, at the end of the third month, that the baby has made another remarkable discovery. It has found not merely that its muscles will contract and jerk and throw its parts about, which is doubtless earlier a great delight to it; but that

the muscles can contract in such a way that the movement will be directed; there is a coordination of the muscular movements. I should like to read to you just these three or four lines from Miss Shinn, who has given perhaps the best story of the development of a baby which has yet been written. This is not merely my opinion, but also the opinion of my psychological colleagues at Cambridge whom I consulted before venturing to express the idea before you, and I find that they take the view that Miss Shinn's book, which is charmingly written, is really done with such precision and understanding of the psychological problems involved that it may fairly be called the best of the books treating of the mental development of a baby. Miss Shinn says, referring to the condition of the child at the end of two months—"Such is the mere life of vegetation the baby lived during the first two months; no grown person ever experienced such an expansion of life—such a progress from power to power in that length of time." She is not thinking of senescence, as we have been thinking of it, but she makes precisely the assertion, which seems to me to be true, that the baby in two months has accomplished an amount of development which no adult is capable of. And now at three months we find another great discovery is made by the baby, that it is possible to bring the sensations which it receives into combination with the movements which it makes. It learns to coordinate its sensory impressions and its motor responses. We hardly realize what a great rôle this adjustment, between what our muscles can do and what our senses tell us, plays in our daily life. It is the fundamental thing in all our daily actions, and though by habit we perform it almost unconsciously, it is a thing most difficult to learn. Yet the baby has acquired the art, though he only gradually gets to be perfect in it. Again we see, at the end of the fourth month, that the baby begins to show some idea of another great principle—the idea that it can do something. It shows evidence of having purpose in what it does. Its movements are no longer purely accidental. At four months we find yet another equally astonishing addition to the achievements of this marvelous baby. He makes the amazing discovery that the two sides of an object are not separate things, but are parts of the same. When a face, for instance, disappears by a person's turning around, that face, to a baby of one month, probably simply vanishes, ceases to exist: but the baby at four months realizes that the face and the back of the head belong to the same object. He has acquired the idea of objects existing in the world around him. That is an enormous achievement, for this little baby has no instructor; he is finding out these things by his own unaided efforts. Then at five months begins the age of handling, when the baby feels of everything. It feels urgently of all the objects which it can get hold of and perhaps most of all of its own body. It is finding that it can touch its various parts and that when its hands and parts of its own body come in contact it has the double

sensation, and learns to bring those together and thereby is manufacturing in its consciousness the conception of the *ego*, personal, individual existence, another great metaphysical notion. Descartes has said—*Cogito, ergo sum*—I think, therefore I am. The baby, if he had written in Descartes's place, would have said—"I feel, therefore I am." The first five months constitute the first period of the baby's development. Its powers are formed, and the foundations of knowledge have been laid. The second period is a period of amazing research, constant, uninterrupted, untiring; renewed the instant the baby wakes up, and kept up until sleep again overtakes it. In the six months' baby we find already the notion of cause and effect. You see he is dealing mostly in metaphysical things, getting the fundamental concepts. That there is such an idea as cause and effect in the baby's mind is clearly shown by the progress of its adaptive intelligence. It evidently has now distinct purposes of its own. It shows clearly at this age also another thing which plays a constant and important rôle in our daily life. It has the consciousness of the possibilities of human intercourse; it wants human companionship. And with that the baby's equipment to start upon life is pretty well established. It has discovered the material universe in which it lives, the succession of time, the nature of space, cause and effect, its own existence, its *ego* and its relationship with other individuals of its own species. Do we get at any time in our life much beyond this? Not very much; we always use these things, which we learn in the first six months, as the foundation of all our thought. By eight months baby is upon the full career of experiment and observation. Everything with which the baby comes in contact interests him. He looks at it, he seizes hold of it, tries to pull it to pieces, studies its texture, its tensile strength, and every other quality it possesses. Not satisfied with that, he will turn and apply his tongue to it, putting it in his mouth for the purpose of finding out if it has any taste. In doing this, hour after hour, with unceasing zeal, never interrupted diligence, he rapidly gets acquainted with the world in which he is placed. At the same time he is making further experiments with his own body. He begins to tumble about; perhaps learns that it is possible to get from one place to another by rolling or creeping, and slowly he discovers the possibility of locomotion, which you know by the end of the year will have so far perfected itself that usually at twelve months the baby can walk. During this period of from five months to twelve the baby is engaged upon a career of original research, unaided much by anybody else, getting doubtless a little help and, of course, a great deal of protection, but really working chiefly by himself. How wonderful it all is! Is any one of us capable of beginning at the moment we wake to carry on a new line of thought, a new series of studies, and to keep it up full swing, with unabated pace, all day long till we drop asleep? Every baby does that every day.

When we turn to the child who goes to school, behold how much that child has lost. It has difficulties with learning the alphabet. It struggles slowly through the Latin grammar, painfully with the subject of geometry, and the older it gets, the more difficult becomes the achievement of its study. The power of rapid learning, which the baby has, is clearly already lessened.

The introduction of athletics affords a striking illustration of the decline of the learning power with the progressing years. When golf first came in it was considered an excellent game for the middle-aged; and you have all watched the middle-aged man play. He was so awkward, he could not do it. Day after day the man of forty, fifty, or even older, would go to the golf field, hoping each time to acquire a sure stroke, but never really acquiring it. The young man learned better, but the good golf players are those who begin as children, twelve and fourteen years of age, who in a few months become as expert and sure as their fathers wished to become, but could not. In bicycling it was the same. Eight lessons was considered the number necessary to teach the intelligent adult to ride a wheel. Three for a child of eight. And an indefinite number of lessons, ending in failure, for a person at seventy. It would have been scientifically interesting to have kept an exact record of the period of time which it took at each age to learn bicycling, but I think enough has been said to convince you that if we could acquire such a measure of psychological development as would enable us to express its rate in figures, we should be able to construct a curve like the curve which I showed you in the third lecture illustrating the decline in the rate of growth, and we should see that during the early years of life, the decline in the power of learning was extremely rapid, during childhood less rapid, during old age very slow. But the great part of the decline would occur during early years.

Here we see the principle of stability, in maturity, which we see also illustrated in structure and growth. The mind acquires its development; it retains that development in the adult a long time. But surely there comes a period when the exercise of the mind is difficult. It requires a great effort to do something new and unaccustomed. A sense of fatigue overwhelms us. I believe that this principle of psychological development, paralleling the career of physical development, needs to be more considered in arranging our educational plans. For if it be true that the decline in the power of learning is most rapid at first, it is evident that we want to make as much use of the early years as possible—that the tendency, for instance, which has existed in many of our universities, to postpone the period of entrance into college, is biologically an erroneous tendency. It would be better to have the young man get to college earlier, graduate earlier, get into practical life or into the professional schools earlier, while the power of learning is greater.

Do we not see, in fact, that the new ideas are indeed for the most part the ideas of young people. As Dr. Osler, in that much-discussed remark of his, has said, the man of forty years is seldom the productive man. Dr. Osler also mentioned the amiable suggestion of Trollope in regard to men of sixty, which has been so extremely misrepresented in the newspaper discussions throughout the country, causing biologists much amusement. But I think that Dr. Osler probably took a far too amiable view of mankind, and that in reality the period when the learning power is nearly obliterated is reached in most individuals very much earlier. As in every class of biological facts, there is here the principle of variation to be kept in mind. Men are not alike. The great majority of men lose the power of learning, doubtless some more and some less, we will say, at twenty-five years. Few men after twenty-five are able to learn much. They become day laborers, mechanics, clerks of a mechanical order. Others probably can go on somewhat longer, and obtain higher positions; and there are men who, with extreme variations in endowment, preserve the power of active and original thought far on into life. These of course are the exceptional men, the great men.

We have lingered so long together studying phenomena of growth, that it is natural to allude to one more, which is as singular as it is interesting, namely, the increase in size of Americans. It was first demonstrated by Dr. Benjamin A. Gould in his volume of statistics derived from the records of the Sanitary Commission—a volume which still remains the classic and model of anthropometric research. Any one, however, can observe that the younger generation of to-day tends conspicuously to surpass its parents in stature and physical development. How to explain the remarkable improvement we do not know. Our discovery of the fact that the very earliest growth is so enormously rapid, makes that earliest period especially important. If the initial growth can be favored a better subsequent development presumably would result. In brief, I find myself led to the hypothesis that the better health of the mothers secures improved nourishment in the early stages of the offspring, and that the maternal vigor is at least one important immediate cause of the physical betterment of the children. Much is said about the degeneracy of the American race, but the contrary is true—the American race surpasses its European congeners in physical development.

You will naturally wish to ask, before I close the series of lectures, two questions. One, how can rejuvenation be improved; the other, how can senescence be delayed. These questions will strike every one as very practical. But the first, I fear, is not an immediately practical question, but rather of scientific interest, for we must admit that the production of young individuals is, on the whole, very well accomplished and much to our satisfaction. But in regard to growing old,

in regard to senescence, the matter is very different. There we should, indeed, like to have some principle given to us which would delay the rate of senescence and leave us for a longer period the enjoyment of our mature faculties. I can, as you have readily surmised by what I have said to you, present to you no new rule by which this can be accomplished, but I can venture to suggest to you that in the future deeper insight into these mysteries probably awaits us, and that there may indeed come a time when we can somewhat regulate these matters. If it be true that the growing old depends upon the increase of the protoplasm, and the proportional diminution of the nucleus, we can perhaps in the future find some means by which the activity of the nuclei can be increased and the younger system of organization thereby prolonged. That is only a dream of the possible future. It would not be safe even to call it a prophecy. But stranger things and more unexpected have happened, and perhaps this will also.

I do not wish to close without one added word. The views which I have presented before you in this series of lectures I am personally chiefly responsible for. Science consists in the discovery made by individuals, afterwards confirmed and correlated by others, so that they lose their personal character. The views which I have presented to you, you ought to know are still largely in the personal stage. Whether my colleagues will think that the body of conceptions which I have presented are fully justified or not, I can not venture to say. I have to thank you much, because between the lecturer and his audience there is established a personal relation, and I feel very much the compliment of your presence throughout this series of lectures, and of the very courteous attention which you have given me.

To recapitulate—for we have now arrived at the end of our hour—we may say that we have established, if my arguments before you be correct, the following four laws of age.

First, rejuvenation depends on the increase of the nuclei.

Second, senescence depends on the increase of the protoplasm, and on the differentiation of the cells.

Third, the rate of growth depends on the degree of senescence.

Fourth, senescence is at its maximum in the very young stages, and the rate of senescence diminishes with age.

As the corollary from these, we have this—natural death is the consequence of cellular differentiation.

RADIOACTIVITY OF ORDINARY SUBSTANCES

By W. W. STRONG

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DURING the latter part of the nineteenth century a great deal of work was done upon electrical discharges in rarefied gases. In 1895 Röntgen made the epoch-making discovery that such a discharge was the source of very penetrating radiations. These radiations he called X-rays on account of their unknown nature, and he found that they possessed the power of making a gas a conductor of electricity by producing in it a great number of positively and negatively charged carriers or ions. Besides ionizing a gas, the X-rays were found to affect a photographic plate just as light rays do and to be able to penetrate thin sheets of the metals and many other bodies which are opaque to light. It was found in the course of experimentation that these X-rays were closely related to the stoppage of the cathode particles or corpuscles, and the phosphorescence on the walls of the vacuum tube which these corpuscles excite. In 1897 J. J. Thomson found that these cathode particles or corpuscles were small negatively charged particles of an apparent mass only one seven-hundredth that of the hydrogen atom and that in a "high vacuum" tube in a strong electric field they acquired a velocity approximating that of light. All the properties of the corpuscles were found to be the same, no matter what kind of gas or electrodes were in the discharge tube. Their mass was found to vary with their velocity in such a way that the whole mass of the corpuscle could be ascribed to the electric charge which it carried. From this most important discovery it was concluded that all the common substances were partly made up of corpuscles, and this conclusion has been strengthened by all later discoveries. After Thomson's discovery, Stokes showed that the sudden stoppage of the corpuscles by the walls of the discharge tube caused intense electromagnetic disturbances to travel out from the point of impact. These disturbances are the X-rays and travel with the velocity of light.

DISCOVERY OF RADIOACTIVITY

When Röntgen announced his discovery, it created a great impetus in the study of everything related to electrical discharges. Now it had been known for a long time that some bodies like the uranium salts phosphoresce when exposed to sunlight, and it occurred to H. Becquerel that such a phosphorescing body might emit X-rays, this

emission being analogous to the origin of X-rays in the phosphorescing glass walls of a vacuum tube. In accordance with this view in 1896 he exposed a photographic plate to uranium sulphate which was covered with copper and aluminium foil and found that the plate was acted upon. Accidentally he found that this action took place, no matter whether the uranium nitrate was phosphorescing or not, and he found that uranium which had never been exposed to sunlight possessed the same property. He found that these radiations from uranium were similar to the X-rays in their penetrating power. This was the first discovery of the possession of radioactivity by a body, *i. e.*, the power of a body to ionize a gas, to affect a photographic plate or to produce phosphorescence.

Madame Curie then took up the problem of finding whether other substances possessed the properties of uranium and found that thorium did. She made a detailed investigation then of all the elements and found that none, with the exception of uranium and thorium, possessed these properties even to the order of the hundredth part of that of uranium. She, however, found that some minerals possessed a greater radioactivity than uranium or thorium, and concluded that these must contain elements more highly radioactive than either of these. After much tedious, but brilliant, work she was able to separate out the very radioactive element radium. As a result of the work of the Curies, and many others, it was found that thorium, uranium, radium and actinium were radioactive, the latter two being intensely so. None of the other elements were found to possess any radioactivity to within the limits of the experimental errors of the method of observation.

The study of these radioactive elements has been the source of very important discoveries in physics. These elements are found to emit spontaneously a continuous flight of material particles, projected with great velocity, and also to be the source of radiations similar to X-rays and called γ rays. We will now describe the material particles, which are of two kinds, the α and β rays.

The α rays consist of positively charged particles shot out by the radioactive body with a velocity approaching that of light. They are readily absorbed by thin sheets of metal foil or by a few centimeters of air. The β rays are far more penetrating in character than the α rays and consist of negatively charged bodies projected with velocities of the same order of magnitude as that of light. As far as known, they are identical with the corpuscles. Of the three kinds of rays, the α rays produce the greatest amount of ionization and the γ rays the least. With a thin layer of unscreened radioactive matter spread on the lower of two plates, say 5 cm. apart, it will be found that the relative order of ionization due to the α , β and γ rays is as 10,000 to 100 to 1, whereas the average penetrating power is inversely proportional

to the relative ionization. The photographic action is due almost entirely to β rays.

THE DISINTEGRATION THEORY

The radioactivity of the radio-elements is not a molecular, but an atomic, property, and the rate of emission of the radiations depends on the amount of the element present and is unaffected by the application of any known physical or chemical forces. In order to explain the emission of positively and negatively charged particles, Rutherford and others consider the radio-elements as undergoing spontaneous changes and that the energy of projection of the α and β rays had previously been stored up in the atom as rapid oscillatory or orbital motion. This breaking up of the atoms is considered to be accompanied by the production of a series of new substances which have distinct physical and chemical properties. For instance, thorium produces an intensely radioactive substance, thorium X, which is soluble in ammonia. Thorium gives rise also to a gaseous product, the thorium emanation, and this is the source of another substance, which is deposited on the surface of bodies in the neighborhood of the thorium, and which is known as the "excited activity" or the "active deposit." If a negatively charged wire is brought into close proximity with thorium salts, the "active deposit" will form upon it. The "active deposit" itself decays into a succession of products.

Following will be given some of the products of the various radioactive elements and some of their properties.

TABLE I.
TRANSFORMATION PRODUCTS. THE THORIUM GROUP

Product	Time to be Half Transformed	Radiations	Range of α Rays	Physical and Chemical Properties
Thorium	$2(10)^9$ yrs.	Rayless (?)		Insoluble in ammonia
Radiothorium	?	α rays	3.9 cm.	
Thorium X	3.6 days	"	5.7 cm.	Soluble in ammonia
Emanation	54 secs.	"	5.5 cm.	Inert gas condensing at -120° C.
Active Deposit	Thorium A	11 hrs.	Rayless	The active deposit is concentrated on the cathode in an electric field.
	Thorium B	1 hr.	α rays	
	Thorium C	Very short	α, β, γ rays	

THE URANIUM GROUP

Uranium	$(10)^9$ yrs.	α rays	3.5 cm.	Soluble in an excess of ammonium carbonate
Uranium X	22 days	β & γ rays		Insoluble in ammonium carbonate.

THE ACTINIUM GROUP

Active Deposit	Actinium	?	Rayless		Insoluble in ammonia Carried down in an actinium solution by adding BaCl ₂ Soluble in ammonia Behaves like a gas The active deposit is concentrated on the cathode in an electric field
	Radioactinium	19.5 days	<i>a</i> rays	4.8 cm.	
	Actinium X	10.2 days	"	6.55 cm.	
	Emanation	3.9 secs.	"	5.8 cm.	
	Actinium A	36 min.	Rayless		
	Actinium B	2 min.	<i>a</i> , <i>β</i> , <i>γ</i> rays		

THE RADIUM GROUP

Active Deposit on Rapid Change	Radium	1,300 yrs.	<i>a</i> rays	3.50 cm.	Allied chemically to barium Inert gas of heavy molecular weight, condensing at -150° C. The active deposit is concentrated on the cathode in the electric field Volatile below 1,000° C. Non-volatile at 1,000° C. Deposited in bismuth in solution.
	Emanation	3.8 days	"	4.33 cm.	
	Radium A	3 min.	"	4.83 cm.	
	Radium B	26 min.	<i>β</i> rays of low penetrating power		
	Radium C	19 min.	<i>a</i> , <i>β</i> , <i>γ</i> rays	7.06 cm.	
	Radium D or Radiolead	40 years	Rayless		
	Radium E	6 days	<i>β</i> rays		
Active Deposit on Color Change	Radium F or polonium or radiotellurium	140 days	<i>a</i> rays	3.86 cm.	

In connection with these tables it may be well to consider the *a* particles a little more. It has been found that the *a* particles of any one product are emitted with the same velocity. It is found that after passing through a definite distance of gas, they then cease to ionize it. If the gas is air under normal conditions of pressure and temperature, this distance will be the range of the *a* particle. All experiments up to the present indicate that the *a* particles of the different products differ only in the speed of projection, this speed determining the range of ionization. Rutherford has found an empirical relation between the range of the *a* particle and its velocity at any point in its path. If *r* is the remaining range after passing through a screen, its velocity is $V = .348 V_0 \sqrt{r + 1.25}$, where V_0 is the initial velocity of the *a* particles emitted from radium C, and is $2.06 (10)^9$ cm. per sec. The initial velocity of expulsion of an *a* particle from a certain product will then be a constant. The value of *e/m* for all *a* rays measured has been found to be the same and to be about $5.07 (10)^3$ electro-magnetic units. It thus follows that all the radio-elements possess the

common constituents, the α and β particles. It has been found that after a certain critical velocity has been reached, the α particles all at once cease to produce any ionization, phosphorescence or photographic action. If a substance emits particles with a velocity less than this critical velocity, we should have no method at present available for detecting them. As to the enormous amount of ionization produced by radium, one can partly grasp it when one considers that an α particle produces about 80,000 ions and one grm. of radium emits about $6 (10)^{10}$ α particles per second. The γ rays also differ in penetrating power. The γ rays from radium and thorium are very much stronger than those from uranium and actinium.

THE RELATIONSHIP BETWEEN VARIOUS ELEMENTS

By actual experiment in the laboratory it is possible to watch the gradual formation of helium and actinium. The rate of formation of helium from radium is known roughly, so that if in any rock the helium formed from radium has not been allowed to escape, a quite accurate estimation of the age of the rock can be made. Radium has also been found by Boltwood and Rutherford to grow in actinium solutions. But by investigating elements which appear together in the rocks it is possible to learn much more. In fact it was from the occurrence of helium in radioactive minerals that the brilliant prediction of the production of helium was made. Boltwood, Strutt and McCoy have shown that the amount of radium present in radioactive minerals always bears a constant ratio to the amount of uranium present. For every gram of uranium there is present $3.8 (10)^{-7}$ grms. of radium. From this coexistence in a constant ratio, one is justified in assuming that radium is a product of uranium. If this is true it is easy to explain the existence of radium in rocks that contain uranium. Otherwise, on account of the short period of disintegration of radium, it would be difficult to account for its distribution through the rocks. It has also been found that minerals of the same age contain uranium and lead in the same ratio, so that it seems quite certain that lead is a disintegrated product resulting from radium. Recent experiments by Rutherford seem to indicate, however, that actinium is not a direct product of uranium, as radium is considered to be. The existence together of various other elements has been used as an argument for their relationship. At present, however, the evidences are very meager and often conflicting. This field of experiment is one that promises very important results, however.

THE DISTRIBUTION OF RADIUM

Considerable work has recently been done by the Hon. R. J. Strutt upon the amount of radium contained in various kinds of rocks widely

distributed over the earth. As this kind of work will probably have considerable geological importance, a few of Strutt's results will be given. A solution of a definite amount of the rock was stored until the equilibrium amount of radium emanation had accumulated. Now, as we have seen that uranium and radium occur in a constant proportion, it is possible to use a mineral of known uranium content and to compare the amount of radium emanation emitted by this and that emitted by the given rock. Following are some of Strutt's results, using $3.8 (10)^{-7}$ grms. of radium as accompanying 1 gram of uranium in uranium minerals.

TABLE II.
RADIUM CONTENT OF IGNEOUS ROCKS

Name of Rock	Locality	Density	Radium per Gram in Grams	Radium per c. c. in Grams
Granite	Rhodesia	2.63	4.91 $(10)^{-12}$	12.9 $(10)^{-12}$
"	Cornwall	2.62	4.80 $(10)^{-12}$	12.6 $(10)^{-12}$
Blue ground	Kimberly	3.06	1.73 $(10)^{-12}$	5.29 $(10)^{-12}$
Leucite basanite	Vesuvius	2.72	1.71 $(10)^{-12}$	4.66 $(10)^{-12}$
Hornblende granite	Assouan, Egypt	2.64	1.26 $(10)^{-12}$	3.32 $(10)^{-12}$
Hornblende diorite	Heidelberg	2.89	1.02 $(10)^{-12}$	2.94 $(10)^{-12}$
Augite syenite	Norway	2.73	.95 $(10)^{-12}$	2.60 $(10)^{-12}$
Granite	Isle of Rum	2.61	.37 $(10)^{-12}$	.97 $(10)^{-12}$
Basalt	Greenland	3.01	.31 $(10)^{-12}$	.94 $(10)^{-12}$
Native iron	"		.218 $(10)^{-12}$	
Meteoritic iron	Thunda		Undetectable	
" "	Virginia		"	
" "	Santa Catarina		"	

RADIUM CONTENT OF SOME SEDIMENTARY ROCKS

Name of Rock	Locality	Radium Content per Gram in Grams
Oolite	Bath	3.00 $(10)^{-12}$
Marble	East Lothian	1.99 $(10)^{-12}$
Roofing slate	Wales	1.32 $(10)^{-12}$
Gault clay	Cambridge	1.09 $(10)^{-12}$
Clay	Essex	.89 $(10)^{-12}$
Red chalk	Hunstanton	.55 $(10)^{-12}$
White marble	India	.28 $(10)^{-12}$
Chalk	Cambridgeshire	.40 $(10)^{-12}$
Deposit from Bath hot springs		.425 $(10)^{-12}$
Cambridge tap water		.400 $(10)^{-12}$
Sea salt		.077 $(10)^{-12}$
Boiler crust, Cambridge		.040 $(10)^{-12}$
Sea salt	Omaha	.0204 $(10)^{-12}$
Sea water	Atlantic	.003 $(10)^{-12}$

These two tables give but a few of the analyses of Strutt. They show the very wide distribution of radium both in the igneous and in the sedimentary rocks. The average radium content of the rocks examined by Strutt is high, whereas that of sea salt is quite small. Strutt finds that the radium content necessary to maintain the earth at a constant temperature is about $1.75 (10)^{-13}$ grms. of radium per cubic centimeter of the earth. This is very much less than the lowest radium content of any of the rocks. For this reason he believes that

radium is to be found only in an outer crust of the earth, at least if the earth is becoming cooler. In making these calculations, the effect of thorium and uranium and the possible radioactivity of ordinary materials is not taken into account. If the heating effect of ordinary materials is of the same order of magnitude as is to be expected from the ionization they produce, the earth's temperature gradient would be many times larger than that observed. Strutt believes this to be an argument that ordinary matter possesses no genuine radioactivity of its own. C. B. Thwing claims, however, that he has been able to find a temperature gradient in small cylinders of the various metals and rocks. At present nothing very definite can be said as to the heating effect of the radioactivity of substances upon the temperature of the earth. Having considered the radioactivity of the various rocks, we will now take up the atmosphere.

RADIOACTIVITY OF THE ATMOSPHERE

It was found after considerable work had been done on ionization that the free air is very considerably ionized. Now in the table of the transformation products of the radio-elements, it will be noticed that several products have the property of condensing on a highly negatively-charged wire. Elster and Geitel and others tried exposing such a wire in the open air and found that there was an active deposit of radium and thorium formed on the wire. The amount of active deposit was found to depend upon the locality and the weather conditions. If the air had been undisturbed for some time as the air in caves and cellars, it was found that the active deposit formed was much greater. Air sucked through the pores of the ground was found to be very active. From these results, Elster and Geitel concluded that the radium and thorium emanations (which behave like gases) ooze up through the ground and percolating waters and have their origin in the radium and thorium in the soil. The emanation then breaks up into the various products as given in Table I. The emanation in this course gives rise to positively charged carriers, which are driven to a negatively charged wire by the electric field. It is to the emanation and its products that the ionization of the air is attributed. Thorium C and radium C give off γ rays, and, as these are very penetrating, they would be the source of a very penetrating radiation, and this latter has been discovered several years ago. The ionization in a closed electroscope is measured, and thick lead screens are then placed around the electroscope, and the ionization is again measured. The ionization in the latter case is found to be very considerably decreased, the penetrating radiation having been largely cut off. Whether all the penetrating radiation can be explained as due to radium C and thorium C will be taken up later.

As the potential of the earth is negative compared with that of the air, the active deposit is dragged down to the surface of the ground and upon the leaves and branches of plants and trees. A hill or mountain top concentrates the earth's field and so receives a greater amount of the active deposit. In this way Elster and Geitel explain the greater ionization on hills and mountains. Experiments show that the active deposit tends to collect on dust particles. These dust particles serve as nuclei for the condensation of raindrops and snowflakes. The deposit resulting from evaporating rain and snow should be very radioactive. This was found to be true by Wilson and Allen. Again, a big rain or snow should carry down most of the active deposit, and as the emanation does not emit γ rays, the amount of γ radiation from the radioactive matter in the air should be very much decreased. The penetrating radiation, if it consists mainly of γ rays, should then become very small. This has been found to be borne out by experiments made by the writer. It must be remembered that the emanation is insoluble in water and as this does not seem to be carried down by water or snow, the products radium C and thorium C would soon be in equilibrium again after the rain or snow.

The effect of the presence of radioactive matter in the atmosphere upon ordinary phenomena is perhaps very great, though at present little is known. It has been found that deep wells and hot springs contain considerable radium. From this Elster and Geitel suggest that the curative effect of thermal springs and the physiological action of the air at high levels may be related to the large amount of radioactive matter present. The presence of radioactive matter, and therefore of ionization, in the air probably plays a very important rôle in the growth of plants. It has been found that vegetables grown in an atmosphere electrified positively are much above those grown in normal fields both in quantity and in quality. The ionization and nucleation produced by radioactive matter in the air are very essential for the condensation of rain and hail, and serve to explain the enormous accumulation of static electricity during thunderstorms. Simpson and others have measured the activity of the air which has blown over the sea and have found it small. Now if most of the radium and thorium emanations come from the pores of the soil and underground cavities, the results obtained by the above investigators would be expected, for, as will be seen from Table II., the radium content of ocean water is very small. Eve has recently measured the ionization over the ocean and has found it to be the same as the ionization over the land, a rather unexpected result. In this state the matter rests at present. A crucial test would be to expose negatively charged wires far out in the ocean and find whether there was any active deposit and to test for the presence of a penetrating radiation. According to *J. Joly*, the distinguished geologist, Eve's results can easily be explained. Geologists have

for some time made an approximate estimate of the age of the oceans by making determinations of the amount of salt which they contain. By analyzing the waters of rivers flowing into the ocean for the salt which they contain and determining the total annual outflow of all the rivers into the ocean, and supposing these constants to have been practically constant during the past, it is easy to make an estimate of the approximate age of the oceans. Now if radium and uranium always exist in a constant proportion, the present radium content of the ocean would have been supplied by the rivers in a comparatively short length of time. For this and other reasons Joly believes that uranium and radium are not always to be found associated together. Now we know that radium has a short period of decay, so that it must constantly be supplied from somewhere. Joly believes that the source is at least partly outside of the earth. This radium is gradually being brought down to the surface. This would account for the ionization over the ocean and the wide distribution of radium over the earth. Elster and Geitel's theory of the escape of the emanation from the upper layers of the soil would still hold true. If radium exists outside the earth, it would be expected that the upper layers of the earth's atmosphere would be highly ionized by the γ rays. This highly ionizing radiation would serve to explain some of the phenomena of atmospheric electricity. According to C. T. R. Wilson, the positive potential of the atmosphere is largely to be attributed to the carrying down of negative charges by raindrops and snowflakes. The upper layers of the atmosphere, being highly ionized and quite good conductors, would conduct the remaining positive charge to places of lower potential and would thus always aid in equalizing the potential of wet and dry regions.

RADIOACTIVITY OF THE METALS

After the discovery that several of the elements were radioactive, it was natural to ask if radioactivity was a universal property of all the elements. Madame Curie's work showed that if the ordinary elements are radioactive at all, they must possess this property to but a very slight degree. In order to detect any possible radioactivity, it was necessary to have very sensitive instruments. It was found by Wilson and Geitel that there is a leakage of electricity through a gas in a closed vessel and that this leak could be measured very accurately by means of an electroscope. Now either the ions are produced spontaneously in the gas, by a radiation which is capable of penetrating the sides of the electroscope or by radiations from the walls of the electroscope itself. Rutherford, Cooke and McClennan have shown that some thirty or forty per cent. is due to a very penetrating radiation supposed to be the γ rays emitted by the radium and thorium products in the air and ground. By using lead screens around the electroscope, they were able to decrease the rate of leak to a certain limiting value

beyond which they were unable to go, no matter how much lead was used. Strutt and others then found that for electroscopes of the same dimensions, the amount of ionization depended on the material forming the walls. For vessels of the same shape and size, lead walls gave the greatest amount of ionization, tin and iron considerably less, aluminium and glass the least of all. Strutt found that different specimens of the same metal gave a different ionization and he therefore concluded that the radioactivity of the metals was probably due to a common impurity.

Patterson then tried using different gases and found that the ionization was proportional to the density. This fact is strong evidence that the ionization is not spontaneous within the gas, but is due to a radiation from the walls of the vessel. Patterson also found for the given vessel which he used (30 cm. in diameter and 20 cm. long) that the current through the gas was independent of the pressure above 300 mm. of mercury and varied directly as the pressure below 80 mm. The ionization was found independent of the temperature up to 450° C. That the ionization was related to the pressure as stated above would indicate that above 300 mm. of mercury all the radiation was absorbed, whereas below 80 mm. it was not all absorbed.

The most complete work on the radiations from the metals and their salts has been done by Campbell. In experiments on the radiations from the metals, Campbell used an aluminium-lined box. Inside this was a wire gauze cage containing a gauze electrode. The cage would allow the admission of radiations, but not of ions. Then by placing two sheets of metal so as to radiate into the cage, one sheet being arranged to slide back and forth, it was possible to measure the ionization produced at different distances of this sliding sheet from the cage. The curve which was plotted from the values of the ionization and the distances gave the values of various constants from which it was possible to determine the values given in a table which is shortly to follow. Before considering this table it is needful to say that the curves indicated (when the external penetrating radiation was cut off): (1) an easily absorbable radiation from the sheets of metal placed aside of the cage; (2) a more penetrating radiation from the same; and (3) the radiation from the gauze cage. When the external penetrating radiation was not screened off, the curves showed in addition an ionization due to (4) the external penetrating radiation; (5) to the penetrating radiation excited by it; and (6) to the easily absorbable radiation also produced. In the table, a is Bragg's constant for the intrinsic absorbable radiations, a constant which corresponds to the range of the α particles of the radioactive elements; s is the number of ions produced per second by the intrinsic absorbable radiation from one square centimeter of the surface of the metal, when totally absorbed in air; λ is the coefficient of absorption of the easily absorbable secondary radiation; s' is the number of ions produced per cubic centimeter by

the easily absorbable secondary radiation from one square centimeter of the metal under the circumstances of the experiment; V is the number of ions produced in 1 c.c. by the intrinsic penetrating radiation from the whole box and lead screen; V' is the number of ions produced in 1 c.c. by the external radiation and the penetrating radiation excited by it.

TABLE III.

Metal	s	s'	V	V'	a	λ
Lead (1)	270	0	10.2	14.2	12	
" (2)	260	0	13.4	26.3	12	
Copper (1)	103	160	2.2	22	9	.6
" (2)	110	91	8.1	27.4	9	.5
Aluminium	117	0	14.8	17	6	0
Tin	144	156	3.1	18.9	9	.5
Silver	146	146	25.5	17.0	8.5	.9
Platinum	74	411	17.3	14.1	12	.4
Gold	78	169	10.4	16.8	10	.6
Zinc	72	51	15.4	16.8	10	.5
Iron	119	124	12.3	10.5	13	.5

λ is the coefficient of absorption of the easily absorbable secondary radiation.

By using a strong electrostatic field, an attempt was made to determine whether the ionizing agents for the intrinsic absorbable radiation were charged. These radiations were found certainly not to be of the β type and very probably to have a nature similar to that of the α rays. No radium emanation was able to be detected from the lead used.

From the constancy of the value of s for the different specimens of the same metal and on account of the variation in the values of a for the different metals, Campbell rightly concludes that there seems to be no doubt but that the ordinary metals are feebly radioactive. In some cases the experimental and theoretical curves agree so well that it would seem that the radiations are homogeneous.

Campbell has also investigated the radioactivity of the metals and their salts in a similar way. He finds that the emission of radiations is an atomic property and that salts prepared by totally different methods and from materials derived from different sources, produce the same ionizing effect. It is only the metal that produces any measurable ionizing effect. The following are some of the results:

Substance	Activity in Arbitrary Units	Substance	Activity in Arbitrary Units
Lead	9.3	Tin	4.4
Lead sulphate (1)	6.8	Tin sulphide (1)	4.1
" " (2)	7	" " (2)	3.9
" " (3)	7.2	" " (3)	3.8
Lead monoxide	8.2	Bismuth	6
Mercury	.9	Bismuth oxide	5.7
Mercurous oxide	.5	Potassium sulphate	70
Mercuric oxide	.6		

Substance	Per Cent. Potassium	Activity of Salt	Activity of Potassium	Weight of Salt
Potassium sulphate (1)	44.7	489	1,090	220
“ “ (2)	“	471	1,050	215
Potassium chloride (1)	52.1	495	951	135
“ “ (2)	“	“	“	139
Potassium iodide	23.5	276	1,180	232
Potassium nitrate	38.6	388	1,005	199
Potassium sulphate (from wood)	44.7	474	1,060	
Orthodase	16.5	201	1,220	
Rubidium alum	16.6	128	768	

The use of numerals after the name of the substance is to indicate that the substance was made by a distinct method of analysis.

It will be noticed that the ionization from potassium and rubidium is very large compared with that from the other metals. It was found that the penetrating power of the potassium and rubidium radiations was also quite large. A given sample of a potassium salt gave the following results:

Number of Sheets of Foil	Ionization	Decrease
0	467	
1	361	106
2	299	62
3	265	34
4	240	25

It will be seen that the rays are very heterogeneous and vary in penetration from that of the very penetrating β rays of uranium downward. Sodium, lithium and ammonium salts showed no more activity than zinc. The rays from rubidium were found less penetrating than those from potassium. The activity of uranium is about a thousand times that of potassium. Photographs were also taken by making use of the rays from potassium and rubidium.

Campbell's results are in consonance with the experiments made some time ago by J. J. Thomson. Thomson showed that rubidium and potassium emit negatively charged particles which were deflected by an electrostatic field in the same way as the ordinary corpuscles.

CONCLUSION

In summing up we find that:

1. Some of the elements, as radium and thorium, are intensely radioactive.
2. Radium is very widely distributed through the rocks of the earth, and in radioactive minerals is found to exist in a constant proportion with uranium.
3. Radium and its products are also to be found in the air and play an important rôle in atmospheric phenomena.
4. The ordinary metals are slightly radioactive, emitting radiations that seem very much like the α radiation from the radio-elements.
5. Potassium and rubidium emit radiations similar to the β rays.

THE INFLUENCE OF DIET ON ENDURANCE AND
GENERAL EFFICIENCY

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EXPERIMENTAL study of the physiological needs of the body for food¹ has indicated that the real requirements of the system, especially for proteid foods, are far below the amounts called for by existing dietary standards, and still farther below the customary habits of the majority of mankind. The ability of the body to maintain a condition of physiological equilibrium, with a true nitrogen balance, etc., on a relatively small amount of nitrogenous food, would seemingly imply that the large surplus so generally consumed constitutes an entirely uncalled-for drain upon the system, as well as upon the pocket of the individual, and without any compensatory gain.

In our experimental study of this question, observations on many individuals have extended over such long periods of time that there is apparently perfect safety in the conclusion that the new dietary standards which aim to conform to the true needs of the body are perfectly adapted to maintain health, strength and vigor indefinitely. Further, the many data obtained in our experimental studies, reinforced by a multitude of personal experiences from all over the world, communicated to the writer, all lead to the view that there is great personal gain in the acquisition of dietary habits that tend toward moderation and simplicity. Renewed health, increased vigor, greater freedom from minor ailments, etc., are so frequently reported as the outcome of temperance in diet, that we are forced to the conclusion that the surplus of proteid food so commonly consumed—amounts far beyond what the physiological necessities of the body demand—is wholly unphysiological and in the long run detrimental to the best interests of the individual. There is seemingly sound philosophy in so changing the customs and habits of our daily life that they will conform more or less closely to our present understanding of the physiological requirements of the body.

It is certainly not presumptuous to assume that physiological experimentation can tell us definitely and concisely how much and what kinds of food are needed to supply the daily waste of tissue and to make good the loss of energy incidental to varying degrees of bodily

¹ See Chittenden: "Physiological Economy in Nutrition" and "The Nutrition of Man," Frederick A. Stokes Co., New York.

activity. This we have sought to ascertain by our studies of the past five years, and confidence in our results is augmented by the fact that when living on a lower level of proteid consumption bodily strength and endurance are unquestionably increased; muscular fatigue and soreness as concomitants of severe or prolonged muscular effort diminish or are wholly wanting; thus raising the suggestion that under true physiological conditions the muscles of the body are capable of more prolonged effort, and with greater freedom from disagreeable after-effects than when the system is charged with an excess of nitrogenous and other waste incidental to large intakes of proteid food. In other words, consumption of proteid food in closer harmony with the true needs of the body is accompanied by a smoother and more efficient working of the bodily machinery; less friction and better results follow a daily diet in which excess is avoided and the intake made to correspond more closely with physiological requirements.

Those who are skeptical of the real value of a relatively low intake of proteid food frequently acquiesce in the general statement that as a physiological experiment it may be quite true that equilibrium, physical vigor, efficiency, etc., can be maintained by a smaller amount of proteid food, but they are inclined to the view that in the long run more abundant supplies of nutriment will be demanded in harmony with the ordinary customs of mankind. This is a reasonable objection, and one that time only can answer. It is quite possible—though not very probable—that an experiment of several years' duration even may fail to show certain deleterious effects which eventually may manifest themselves, assuming that the body does actually need more proteid food than our experimental results imply. This may be a purely theoretical objection, but it is one that is deserving of some consideration, since it is unquestionably true that there are many factors in the broad subject of nutrition not yet fully understood, and there are many phases of proteid metabolism not wholly clear. So far as any experimental evidence is concerned, however, there is nothing, in the writer's opinion, that can be construed as giving weight to this objection. Neither are there any observations bearing on the customs or habits of peoples or communities that can be adduced in favor of possible danger to the individual from a continued intake of proteid food in harmony with our experimental data; certainly none that is not equally susceptible of plausible explanation on some other ground.

As has been stated in another place,² a daily intake of 60 grams, or two ounces, of proteid is quite sufficient to meet the needs of a man of 70 kilograms body-weight, and this without increasing unduly the amount of non-nitrogenous food. In fact, for a man of the above weight doing an ordinary amount of work, the total calorific value of

² "The Nutrition of Man," p. 272.

the daily food need not exceed 2,800 calories. As compared with the ordinary statements of the body's needs, this means a saving of one half in the amount of proteid food and about one fifth in the amount of non-nitrogenous food daily. That these smaller amounts of food are quite sufficient to meet the needs of the body is indicated by the condition of the subjects after many months of living at these lower levels. Especially noticeable, because at that time wholly unexpected, was the decided gain in bodily strength and endurance manifested by all the subjects of experiment. This gain was spoken of as gain in "total strength," but the element of endurance was incorporated therein, since the final product³ was a compound of the dynamometer tests of individual muscles and the number of times the individual could pull up and push up his body on the parallel bars. The natural interpretation of the results obtained was that the increased muscular efficiency was a direct or indirect result of the lowered proteid metabolism of the body. In other words, it might be reasoned that the smaller consumption of proteid food was a nearer approach to normal conditions, and as a result there was manifested an increased muscular efficiency. However this may be, bodily strength and endurance were certainly increased, and the question naturally arises, will this improved state of the body continue for any length of time under such conditions of diet? In other words, may we expect to find an improved physical condition of the body in following habits of life which seemingly accord more closely with true physiological needs, avoiding that excess of food intake that the common practises of mankind sanction?

One of the first subjects experimented with by the writer was Horace Fletcher, who in 1903 spent several months in our laboratory⁴ and was at the same time carefully tested by Dr. William G. Anderson, director of the Yale Gymnasium, as to his physical condition. For some five years Mr. Fletcher had practised a certain degree of abstinence in the taking of food with, as he believed, important economy, *i. e.*, great gain in bodily and mental vigor and with marked improvement in his general health. He found that under his new method of living he was possessed of a peculiar fitness for work and with freedom from the ordinary fatigue incidental to extra physical exertion. In the laboratory observations made at that time, it was found that he was not metabolizing more than fifty grams of proteid per day, while at the same time his body was essentially in a condition of nitrogen equilibrium. Dr. Anderson, as the result of his observations on Mr. Fletcher, concluded that, considering his age, he had never seen an individual able to work in the gymnasium with fewer noticeable bad results, since he was able to do the work of trained athletes and not

³ "Physiological Economy in Nutrition," p. 259.

⁴ See POPULAR SCIENCE MONTHLY, June, 1903, p. 127.

give marked evidences of over-exertion, although not in training. At the time these experiments were tried Mr. Fletcher weighed one hundred and fifty-seven and a half pounds, and was in his fifty-fourth year.

While, naturally, we have not been able to obtain daily records of the quantity of food taken by Mr. Fletcher during the past four years, observations made from time to time have confirmed his general statement that he lives essentially at this same low level of proteid metabolism. In June, 1907, Mr. Fletcher was again at New Haven for some weeks, thus giving us an opportunity to test his rate of nitrogen exchange and his physical condition. It was found that the amount of nitrogenous or proteid food consumed daily never exceeded sixty grams, and that his nitrogen metabolism averaged not far from seven grams per day. His body-weight was found to be one hundred and seventy-seven and a half pounds. We thus had an opportunity of testing the physical endurance of a man who has for at least nine years practised a degree of physiological economy in nutrition, which means a daily consumption of proteid food in amount less than one half that called for by the ordinary dietary standards. It would seem reasonable to suppose that if a low nitrogen intake is destined eventually to prove detrimental to the individual, some sign of such deleterious effect would manifest itself during this period of time. If, on the other hand, consumption of proteid food in harmony with the lower dietary standards which the writer is disposed to advocate on the basis of his experimental results, is beneficial to the individual, then one might expect to find a continuance of the same physical vigor noted in the earlier observations on Mr. Fletcher, in spite of the fact that at this date the subject was nearly fifty-nine years of age.

Through the kindness of Dr. Anderson, of the Yale Gymnasium, Mr. Fletcher was subjected to a variety of tests, the outcome of which is best presented in the words of Dr. Anderson, as given to the writer in a report made under date of June 28, 1907.

On June 11, 1907, Mr. Fletcher again visited the Yale Gymnasium and underwent a test on Professor Fisher's dynamometer. This device is made to test the endurance of the calf muscles. (Soleus and gastrocnemius.) The subject makes a dead lift of a prescribed weight as many times as possible. In order to select a definite weight the subject first ascertains his strength on the Kellogg mercurial dynamometer by one strong, steady contraction of the muscles named—and then he finds his endurance by lifting three fourths of this weight on the Fisher dynamometer as many times as possible at two- or three-second intervals. One leg only is used in the lift, and, as indicated, the right is usually chosen.

Mr. Fletcher's actual strength as indicated on the Kellogg machine was not quite 400 pounds, ascertained by three trials. In his endurance test on the Fisher machine he raised 300 pounds 350 times and then did not reach the limit of his power. Previous to this time Dr. Frank Born, the medical assistant at the gymnasium, had collected data from 18 Yale students, most of whom were trained athletes or gymnasts. The average record of these men was 87.4 lifts, the extremes being 33 and 175 lifts.

It will be noticed that Mr. Fletcher *doubled* the best record made previous to his feat and numerous subsequent tests have failed to increase the average

of Mr. Fletcher's competitors. Mr. Fletcher informs me that he has done no training nor has he taken any strenuous exercise since February, 1907. On two occasions only during the past year he reports to have done hard work in emergencies; once while following Major General Wood in the Philippines in climbing a volcanic mountain through a tropical jungle on an island near Mindanao for nine hours; and once wading through deep snow in the Himalayan Mountains, some three miles one day and seven miles the next day, in about as many hours. This last emergency experience came through being caught in a blizzard near Murree, in northern India, at 8,500 feet elevation, on the way to the Vale of Kashmir. These two trials represented climatic extremes and Mr. Fletcher states that neither the heat nor the cold gave him discomfort, a significant fact in estimating physical condition.

Before the trial on the Fisher ergograph, the subject's pulse was normal (about 75); afterwards it ran 120 beats to the minute. Five minutes later it had fallen to 112. No later reading was taken that day. The hands did not tremble more than usual under resting conditions, as Mr. Fletcher was able to hold in either hand immediately after the test a glass brimming over with water without spilling a drop. The face was flushed, perspiration moderate, heart action regular and control of the right foot and leg used in the test normal immediately following the feat. I consider this a remarkable showing for a man in his fifty-ninth year, 5 feet 6½ inches in height, weighing 177½ pounds and not in training.

In order to make a more thorough test of Mr. Fletcher's powers of endurance under varying degrees of physical strain he underwent on the 17th, 18th, 19th, 21st and 22d of June, 1907, the following:

1. Going up 32 steps of a spiral stairway at natural speed.
2. While in the lying position, raising the trunk to a vertical position a prescribed number of times and continuing as many more times, at will, as agreeable.
3. While standing with arms upraised to the full bending forward and downward, touching the floor with the fingers without bending the knees.
4. While holding two 25-pound iron dumb-bells, first flexing the elbows and then raising the weights to arm's length above the head.
5. A daily test on the Fisher dynamometer, not for endurance, but for measuring pulse acceleration.

It became necessary to make a change in the character of the movements on the final day of the test on account of the chafed condition of the subject's skin, and we added:

6. "Running in place," with knee lifting forward and upwards to the extreme possible height.
7. Rapid extension of the arms upward, outward and downward.
8. Same as 7, but holding one-pound wooden bells in each hand.

Pulse readings were taken before and after each test, and in the following report the average pulse for each exercise is given:

After *quickly* climbing 32 spiral steps, five trials, the average pulse was 115.2 beats to the minute.

After trunk raising, five trials, 50, 60, 70, 100 and 100 times; the latter two trials in one day, five hours apart; average pulse, 115.2 beats.

After trunk bending, five trials, 60, 100, 150, 200 and 300 times; the latter two trials in one day, five hours apart; average pulse, 150 beats.

After lifting the 25-pound bells, five trials, 5, 5, 10, 10 and 10 times; average pulse, 138 beats.

After tests on the Fisher dynamometer, four trials, 50, 60, 60 and 60 times; average pulse, 120 beats.

After rapid arm work for three minutes, average pulse, 156 beats.

After similar work holding wooden bells (two minutes), average pulse, 156 beats.

After running in place as rapidly and as strenuously as possible for one minute, average pulse, 144 beats.

After each test the respiration and heart action, while active, were healthy, and, under such conditions, normal.

There was not the slightest evidence of soreness, stiffness or muscular fatigue either during or after the six days of the trials. The chafing of the skin was due to the rubbing of the "tights" worn while lying down and raising the trunk. Mr. Fletcher made no apparent effort to conceal any evidences of strain or overwork and did not show any. He informs me that he felt no distress whatever at any time.

During the thirty-five years of my own experience in physical training and teaching I have never tested a man who equalled this record. The latter tests, given in June, 1907, were more taxing than those given in 1903, but Mr. Fletcher underwent the trials with more apparent ease than he did four years ago. What seems to me to be the most remarkable feature of Mr. Fletcher's tests is that a man nearing sixty years of age should show progressive improvement of muscular quality merely as the result of dietetic care and with no systematic physical training.

Such a record of endurance as this, especially when made by a man fifty-nine years of age, can hardly fail to attract our attention. Further, when it is remembered that the subject of this test was not in training, the question naturally arises as to the cause of this phenomenal showing. Why a man of fifty-nine years of age, without training, should be able to far surpass the record for endurance made by young and vigorous athletes can only be surmised, but it certainly seems plausible to assume that the explanation is to be found in the careful dietary habits which this man has followed for the past nine years. In any event, it is fair to suppose that habits of life, leading to a relatively small intake of nitrogenous food, are not inimical to a general condition of physical efficiency and muscular endurance. We may go even farther and assume that the remarkable showing made by this subject is due directly to his temperate dietary habits. Mr. Fletcher would doubtless lay special stress upon his habit of thorough mastication and of abstaining from eating until the appetite strongly demanded food. This phase of the subject we need not discuss here. The main point is that this particular subject has during these nine years made a practise of consuming daily a quantity of proteid food not more than one half that demanded by ordinary dietary standards. In other words, his habits of living have been essentially in accord with the conclusions arrived at by our experimental studies bearing on the requirements of the body for proteid food.

We see in these results possible progressive muscular recuperation after middle life by means of diet alone. If a man by careful attention to his diet can show progressive gain in endurance and general efficiency after fifty without systematic training, it is a fact well worth knowing. In any event, the data afforded by this particular subject corroborate in striking fashion the conclusions arrived at by laboratory experimentation, and tend to confirm the view that there is perfect safety and probable gain to the body in a system of dietetics which approximates to true physiological requirements and avoids undue excess.

JEAN LOUIS RUDOLPHE AGASSIZ¹

BY PROFESSOR EDWARD S. MORSE

PEABODY MUSEUM, SALEM, MASS.

JEAN LOUIS RUDOLPHE AGASSIZ was born in Motier, Switzerland, May 28, 1807, and died in Cambridge, December 14, 1873.

He was one of the great naturalists of the world, a student of Cuvier, beloved by Humboldt, counting every distinguished name in science as an admirer and idolized by his associates. At the age of twenty-four he had an international reputation. He had conferred upon him many degrees, one of which was the doctor's degree of medicine and surgery, in the preparation for which Von Siebold says he prepared seventy-four theses on anatomical, pathological, surgical and obstetrical subjects, also investigations in materia medica, medicina forensis and the relation of botany to these topics.

He studied at the medical school at Zurich, the University of Heidelberg and at the University of Munich. Investigations of the widest diversity in natural science were embodied in 415 papers, memoirs and books, many in quarto and folio, representing nearly ten thousand pages and a thousand plates.

Besides his profound attainments as a naturalist he was equally remarkable as a teacher and most eloquent as a lecturer. Always enthusiastic in his own work, he had the further power of inspiring this enthusiasm in others. At the age of twenty-three, in a letter to his brother, he said: "What troubles me is that the thing I most desire seems to me, at least for the present, farthest from my reach, namely, the direction of a great museum." He little foresaw that thirty-one years from that time he would see the inauguration with pomp and circumstance of the great museum at Cambridge of which he was the originator and director. Nor could he have anticipated that his son, profiting by his engineering and geological studies in the Lawrence Scientific School with which this museum was affiliated, should use that knowledge in securing the fortune by which the museum has expanded far beyond the most ardent imagination of its founder.

In the very prime of his manhood, in the very height of his fame,

¹ Read at the unveiling of the Agassiz tablet at the Hall of Fame, New York, May 30, 1907. In the preparation of this brief address I am indebted to Mrs. Elizabeth Agassiz's charming tribute to her husband in her "Life and Letters of Louis Agassiz" and to Marcou's "Life of Agassiz."

he came to our country, and by his enthusiasm, his eloquence, his winning and democratic ways, he won the hearts of all, and from his advent here may be dated the wide-spread love of natural science among the masses.

Agassiz's contributions as a naturalist covered the entire range of the animal kingdom. A study of his bibliography exhibits communications, papers and memoirs on every Cuvierian class. A further study of this bibliography indicates that, as a young man, he grappled with some of the most difficult groups of the animal kingdom. The fishes had been one of the most distracting divisions of the higher animals. The limitations of their genera, the homologies of their bony structure, had daunted most zoologists who confined their work to the description of species. Agassiz's first important work was the "Fishes of Brazil," based upon material brought home by Martius and Spix. This was done at the age of twenty-two. The work was written in Latin, dedicated to Cuvier, and illustrated with a folio of ninety plates. At the age of twenty-three he issued his prospectus of the natural history of the fresh-water fishes of central Europe, which was completed twelve years after, accompanied by a folio atlas of forty-one colored plates.

Difficult as was this task, he wrestled with a still more difficult one, namely, the "Fossil Fishes," and in nine years had completed this remarkable work in five quarto volumes with 400 colored folio plates. This publication alone placed him in the front rank of naturalists. An eminent geologist has written in regard to this work that Agassiz's power of classifying fossils and his success in reducing to order thousands of specimens of fishes, a great many of which were perfect puzzles to every one, was simply marvelous. The echinoderms, with their complicated covering of curious plates, spines and minute appendages, formed another most difficult group for study. From the number of fossil species in the rocks in his neighborhood Agassiz was led to a minute examination of both living and fossil forms which culminated in his great monograph of echinoderms with many plates.

The prodigious extent and character of the work done before he was thirty years old may be appreciated when it is stated that on a meager salary of \$400 a year he established a lithographic press at Neuchatel, he employed two skilful artists, published a number of parts of his monograph of the echinoderms, several parts of his fossil fishes, made a profound study of the glacial phenomena of the Alps as well as of the geology and paleontology of the Jura and superadded to all this work the monographing of two molluscan genera, *Mya* and *Trigonia*. Ernest Favre, in his biographical notice of Agassiz, says, in regard to this period of his life, that he displayed an incredible energy, of which the history of science offers, perhaps, no other example.

His original way of dealing with subjects is well illustrated in his studies of fossil bivalve mollusca. It had been customary to describe the external markings of the shell and when possible the muscular impressions within. Agassiz soon realized the importance of studying the interior contour of the shell, and forthwith proceeded, by means of casts, to bring to light the relations of these fossils with their living representatives. His maxim was to have abundant material—thousands of specimens, if necessary—for any proper research. In studying glaciers he literally rode on the back of one for weeks at a time. He furthermore urged his students to read all that had been written on a subject before publishing.

Agassiz not only defined many new species of animals in various classes, but he was continually dwelling on the affinities and homologies among the various groups; more particularly their classification and their geographical and stratigraphical distribution. His studies in embryology and his familiarity with the work of Von Baer led him to recognize the general truth that the young of higher animals in their respective groups resembled the mature forms of animals lower down in the scale. From these studies he soon grasped the greater conception that this principle was carried out in time as well, and that fossil animals in the early horizons of geological history resembled the embryonic or early condition of higher animals now living and hence the idea of comprehensive or prophetic types. This same broad grasp of fundamental principles was remarkably illustrated in his studies of glacial phenomena in the Alps. One of his biographers says, "With his power of quick perception, his unmatched memory, his perspicacity, and acuteness, his way of classifying, judging and marshaling facts, Agassiz promptly learned the whole mass of irresistible arguments collected patiently during seven years by Charpentier and Venetz, and with his insatiable appetite and that faculty of assimilation which he possessed in such a wonderful degree he digested the whole doctrine of the glaciers in a few weeks," and added a great many new and important facts.

From his study of the glaciers of the Alps he soon announced his belief that the whole northern hemisphere had at one time been covered by an ice sheet. The various records of this vast sea of ice which had been interpreted by the most eminent geologists as the result of diluvial action and flowing mud he rightly attributed to the action of ice. In the face of the most strenuous and even bitter opposition he triumphantly established the former existence of the Great Ice Age. Subsequent studies, while modifying the limitation of the great ice sheet, have only strengthened the views of Agassiz.

Agassiz's absorbing interest in the structural relations of animals led him to define with greater accuracy the limitation of various groups.

As a student of the great French naturalist, Cuvier, he became an eloquent advocate of the existence in nature of four great branches of the animal kingdom. He was early convinced that branches, classes, orders, families and genera had as distinct an existence in nature as species, and his life work was to make clear and rigid their definition. His eager desire to understand the relations existing between obscure forms was expressed one day in a private talk to his pupils, when he earnestly exclaimed, "The lamprey eel has been my puzzle and my misery for twenty years."

Not only in many technical essays, but as an eloquent teacher, he made these principles of classification so plain that vast audiences were able to grasp his conceptions. Those who heard his lectures on the subject will never forget the vivid way in which he impressed upon his auditors these views emphasized by graphic blackboard drawings.

In his methods of study in Natural History he presented in a popular form the leading features of his belief in the systematic relations of animals as embodied in his famous "Essay on Classification." The following quotation from his *Methods of Study* will indicate the ideas which were surely preparing the ground for the acceptance of the theory of evolution:

Man is the crowning work of God on earth, but though so nobly endowed, we must not forget that we are the lofty children of a race whose lowest forms lie prostrate within the water, having no higher aspirations than the desire for food; and we can not understand the possible degradation and moral wretchedness of Man, without knowing that his physical nature is rooted in all the material characteristics that belong to his type and link him even with the fish. The moral and intellectual gifts that distinguish him from them are his to use or to abuse; he may, if he will, abjure his better nature and be Vertebrate more than Man. He may sink as low as the lowest of his type, or he may rise to a spiritual height that will make that which distinguishes him from the rest far more the controlling element of his being than that which unites him with them.

Not only by such expressions just quoted, but in other statements, he certainly prepared the way for the more prompt recognition of Darwin's views.

Inspired by the belief in the existence in nature of categories of structure, he strengthened old homologies and established many new ones. In representing the four Cuvierian branches by schematic lines, he did not draw a series of lines one above the other, or enclose each group by sharply defined brackets, but drew these lines, parallel it is true, but side by side in an ascending scale, slightly overlapping. He endeavored to indicate by such a diagram his belief, which was correct, that the higher members of a lower group were more advanced in structure than the lower members of a group next above. Thus while the vertebrates were higher as a branch than the articulates, the highest class of the articulates, the insects, were higher in structure than many

of the lowest vertebrates. In this way he broke up the idea that the animal kingdom formed a continuous ladder in creation, from the lowest form to man. This was an important approach to a phylogenetic diagram, for it was readily seen that the lower forms in each great division had closer affinities with each other than existed among the higher members. In other words, that his schematic lines should not be made parallel, but should converge below—a genealogical tree in fact. His generalized or prophetic types lend overwhelming support to this conclusion.

It has been repeatedly said, and with truth, that Agassiz's teachings paved the way for the prompt acceptance of the theory of evolution—first, because he familiarized the great public with a structural knowledge of the animal kingdom and the affinities existing between the different groups, and, second, because he demonstrated the recapitulation theory of Von Baer, and added the great conception that the history of the animal kingdom from the earliest geological horizons added further proof of these principles. Agassiz came to an environment well fitted to encourage him. He came to an intellectual center famous for its leadership in science and letters, but the hearty reception accorded him in widely separated regions leads to the conviction that had he settled anywhere in the Country he would have inspired the same enthusiasm and induced hard-headed legislators everywhere to have voted large appropriations, and private citizens to contribute generous sums. It required only his touch to bring into recognition names among us that had before his magic influence been known only in limited circles. Men of the caliber of those of 1846 are a thousand times more widely known to-day, not because of the changed character of the public press, which celebrates with equal prominence and impartiality girl graduates of a public school and men who have revolutionized the world by their inventions, but because he made us appreciate the worth of an investigator. Our nation has always believed in education and public schools, and hence has universally approved of high endowments for educational purposes. His great plea and one that had its effect on the legislators was that the museum was an educational institution, that it was to be opened every day free to the public and that it was a sound investment, though its dividends were wholly intellectual. A few personal reminiscences may be of interest at this point. In the early part of the civil war, one of our class enlisted and received an appointment as an officer of the line—the rest of us bought a fine sword and presented it to him. On showing the sword to Agassiz, he instantly threw himself into the attitude of a fencer and became absorbed in thrust and parry, utterly unconscious of our amazement at his earnestness and skill. We learned afterwards that as a student at Munich he had not only fought a number of student duels

in which he was always the victor, but on one occasion he had challenged a whole class, whereupon the best swordsman was selected to meet him, when he insisted that he had really challenged every member of the class to fight. After four had crossed swords with him and been vanquished the remainder were quite ready to retire. Agassiz with all his genius had no capacity for business and, as he admitted, was incapable of doing a simple sum in addition; nevertheless, he plunged into investigations which to carry out involved the expenditure of large sums of money. Mrs. Agassiz in the charming tribute to her distinguished husband says:

He was frugal in his personal habits. At this very time, when he was keeping two or three artists on his slender means, he made his own breakfast in his room and dined for a few cents a day at the cheapest eating houses. But where science was concerned the only economy recognized, either in youth or old age, was that of an expenditure as bold as it was carefully considered.

While expressing his great appreciation of the many honors given him by distinguished societies, he seemed to be indifferent to the certificates of these honors. As an illustration of this indifference I may cite an experience that a few of us had with an enormous mass of pamphlets which were unpacked and which Agassiz asked us to classify and arrange by their respective subjects. Intermixed with these pamphlets were numerous diplomas, some of them badly wrinkled, attesting to his election as associate or honorary member of great societies and academies, university degrees, and, if I remember rightly, medals of honor also.

Very few are aware of the profound influence Agassiz's devotion to his work and his enthusiasm had on the character of Harvard College. To apply an expression of Froude, he came in to this staid college community like a meteor out of the clear sky. One day as he crossed the college campus I drew a sketch of him: it contradicts every custom and tradition of the Harvard professor since the foundation of the college in 1638. On his head a soft hat, in his pockets his hands, in his mouth a cigar! President Eliot, in his address at the Agassiz commemorative meeting of the Cambridge Historical Society, said that Agassiz's ability in securing from hard-fisted members of the General Court large appropriations for his museum, excited the envy of other departmental chiefs. Yet in obtaining these large sums from the legislature, and from private citizens as well, he finally provoked the habit of liberal giving to the college as a whole. Thus the college grew into a university, and the inception of this growth dates from the advent of Agassiz. His advice was followed in shaping the work of the Smithsonian Institution. A similar influence must be accredited to him in enlarging the work of the United States Coast and Geodetic Survey. Professor Bache, then superintendent, was an intimate friend

of Agassiz, and the broadening views of Agassiz on the work of this important branch of the national government was marked. The American Association for the Advancement of Science is indebted to Agassiz for the remodeling of the old Society of Geologists and Naturalists along the line of the British Association, of which he had long been a member. He became president of the association in 1851. Agassiz, Bache and Henry were the leading spirits in originating the National Academy of Sciences. The character of the man is indicated by the fact that the highest authorities in art, science and literature were immediately drawn to him and found in him a true friend and a charming companion.

The students associated with Agassiz at the dedication of the museum in Cambridge with few exceptions became heads of many of the great museums of the country.

Professor Hyatt was, at the time of his death, custodian of the Boston Society of Natural History. Dr. Scudder had preceded him in the same office. Professor Shaler continued at Harvard as professor of geology and became dean of the Lawrence Scientific School. Professor Putnam, one of the originators of the Peabody Academy of Science in Salem, and for years director of its museum, is now director of the Peabody Museum at Cambridge. Professor Verrill has been professor of zoology at Yale since his graduation and is director of the museum at New Haven. Professor Packard, for some years director of the Peabody Museum at Salem, was at the time of his death, professor of zoology at Brown University. Professor Bickmore was closely identified with the inception of the American Museum of Natural History in New York, was its first director and continued in the office for many years, and the writer has for twenty-seven years been director of the Peabody Museum at Salem.

This record is certainly a credit to the great teacher whose pupils adhered to the initial impulse imparted to them by their master.

At the age of twenty-two, in a letter to his father, he wrote:

I wish it may be said of Louis Agassiz that he was the first naturalist of his time, a good citizen, and a good son, beloved by those that knew him. I feel within myself the strength of a whole generation to work toward this end, and I will reach it if the means are not wanting.

This boyish prophecy was fully established as attested by the glorious records of his life.

NOTE TO THE EDITOR: In view of the distracting state of zoological nomenclature at the present time with the habit of regarding the slightest deviation in structure as of generic value with the result that nearly every species has a separate generic name, it may be regarded as a misfortune that Agassiz could not have established on a sure and enduring foundation his various categories of classification. In a conventional manner it would be profitable to adopt his definitions, even if the groups have no real existence in nature. Only in this

way can relief be secured from a condition which is confusing and exasperating.

As an illustration of Agassiz's firm adherence to his principles of classification so clearly elaborated in his famous essay on the subject, I may be excused for giving a letter written to me a few days after I had explained to him my views regarding the systematic position of the Braciopoda:

Your statements of last Saturday haunt me and I can not rest before I have seen more of your facts concerning the Anneliden affinities of the brachiopods. The most telling evidence *in your favor*² you have never yet alluded to, at least not in my presence. But I must be cautious and wait till I see and hear more of your facts. When and where can I see you again? This is not a question of structural complication.

Very truly yours,
L. AGASSIZ.

CAMBRIDGE, Jan. 2, 1871.

² The italics are his.

THE ORIGIN OF SLAVERY AMONG ANTS

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AMERICAN MUSEUM OF NATURAL HISTORY

THE researches of the past few years have materially changed our views on the significance and phylogenetic origin of the so-called slave-making instincts among ants. And although the subject still involves many unsolved problems, we are now in a position to look back on its history and marvel at our too implicit confidence in certain analogies, at our neglect of the basic principles of phylogenetics, and at the inept questions we so long persisted in asking.

Slavery, or dulosis, is a rare phenomenon among ants. In its pure form it is known to occur only in two of the several thousand described species, namely, in the sanguinary or blood-red slave-maker (*Formica sanguinea*) and the amazon (*Polyergus rufescens*). These species, with their various subspecies and varieties, are peculiar to the north temperate portions of Europe, Asia and America. The phenomenon was first discovered by J. Pierre Huber (1810)¹ and most completely described by him and by Forel (1874)² These investigators, of course, fixed their attention on the behavior of the workers. To this aspect of the subject later writers have added little of importance, and have merely fallen into a natural error of continuing in the same path as their illustrious predecessors. This was the case, for example, with Darwin³ and with Wasmann, who for the past quarter of a century has been observing the slave-making ants of Europe. Huber and Forel showed that the workers of *F. sanguinea* and *P. rufescens* make periodical forays on colonies of ants belonging to the *F. fusca* group, carry home the worker cocoons and larvæ, and permit some of these to hatch and to survive with them in the same formicary. An eminently predatory species thus comes to live in intimate symbiosis with workers of an alien species which are said to function as slaves, or auxiliaries. *F. sanguinea* is a powerful and very plastic species which continues to exercise all the fundamental ant instincts in the presence of its slaves. It can excavate galleries in the soil, obtain its own food and bring up its own young. *Polyergus*, however, is abjectly dependent on its auxiliaries. It is no longer able to excavate a nest, care for its own

¹ "Récherches sur les mœurs des fourmis indigènes," Paris et Genève, 1810.

² "Les Fourmis de la Suisse," Zürich, 1874.

³ "On the Origin of Species by Means of Natural Selection," third edition, London, John Murray, 1861, p. 244.

offspring, or even to take food, except from the tongues of the alien workers. It is therefore properly considered as representing a more advanced stage of parasitism than *sanguinea*. A few species belonging to the Myrmicine genera *Tomognathus* and *Strongylognathus* seem to possess analogous instincts, but too little is known of their habits to enable us to make very definite statements concerning them.

It was, of course, impossible to do more than speculate on the phylogeny of the slave-making instincts of *sanguinea* and *Polyergus* without a knowledge of the ontogenetic source and development of these instincts, and as these are social activities, that is, carried out simultaneously by a number of cooperating organisms, it was necessary to learn something about the origin and development of the ant colony as a unit. The bearing on the origin of slavery of the obvious and fundamental fact that there is a double ontogeny and phylogeny in social organisms, namely, one of the colony as well as one of the individual, has been appreciated only within the past few years and has completely changed the aspect of the subject.

In the great majority of ant species the colony arises and develops in the following manner: The single female, or queen, after mating during her marriage flight, descends to the earth, divests herself of her wings, digs a small cell in the soil, or enters some preformed cavity under a stone or in the tissues of a plant, lays a number of eggs, feeds the resulting larvæ with a salivary secretion, and guards and nurses them till they mature and constitute a brood of diminutive workers. These now proceed to enlarge the nest, to forage for food, both for themselves and their mother, and to care for the succeeding broods of young. The queen thenceforth gives herself up exclusively to feeding from the tongues of her offspring and to laying eggs. The colony grows apace, the workers increasing in number, size and polymorphism with successive broods. Eventually males and virgin queens are produced, though often only after the expiration of several years, when the colony may be said to have completed its ontogenetic development.

It will be seen from the foregoing description that the mother queen lapses from the position of an independent organism with remarkable initiative to that of a parasite dependent on her own offspring. The latter stage in her life is of much longer duration than the former. This singular ontogenetic change in the instincts of the queen should be noted, as it foreshadows an important phylogenetic development exhibiting two different modifications, one of which is excessive, the other defective, in comparison with the primitive and independent type of colony formation. The excessive, or redundant, type is known to occur only among the Attine ants of tropical America. These raise fungi for food and are quite unable to subsist on any other substances. The queens are often very large, especially in the typical

genus *Atta*, and not only manage to bring to maturity a brood of workers, but at the same time, as von Ihering,⁴ Goeldi⁵ and Jacob Huber⁶ have shown, have energy to spare to devote to the cultivation of a fungus garden. With the appearance of the first brood of workers, however, these queens, like those of most ants, degenerate into parasites on their own progeny.

This dependent stage, which, as I have said, is of much greater duration than the independent stage in the long life of the queen, leads to a number of phylogenetic developments of the defective type. These developments first manifest themselves in the adoption of young queens by adult workers of their own species. A word of explanation will make this clear. In the colonies of many species of Formicidæ we find several queens—in fact, there are comparatively few ants whose adult colonies do not contain more than one of these fertile individuals. And a study of the growth of such colonies shows that the supernumerary queens are either daughters of the original single queen that founded the colony, or have been adopted from other colonies of the same species. Hence these queens are either virgins, or have been impregnated by their own brothers (adelphogamy of Forel) in the parental nest, or have been captured by the workers and carried into the nest after descending from their nuptial flight. This forcible adoption leads necessarily to a complete suppression of the independent stage in the life of such queens. I have shown, in another article, that merely removing a queen ant's wings with tweezers will at once call forth the dependent series of instincts, and the same result is undoubtedly produced when the workers deälate the virgin or just-fertilized queens of their own or other formicaries. Such queens, finding themselves surrounded by a number of accomplished nurses, the workers, proceed at once to act like old queens that have already established their colonies and brought up a brood.

From this condition of facultative adoption to an obligatory adoption of the queen by workers of her own species is but a step. And here there are three possibilities: first, the queen can establish a colony only with the aid of workers of her own species and of the same colony. This condition seems not to obtain among ants, although it is well known in the honey-bees. Second, the queen must either be adopted by the workers of her own species of the same or another colony, or

⁴ "Die Anlage neuer Kolonien und Pilzgärten bei *Atta sexdens*," *Zool. Anz.*, XXI., 1898, pp. 238-245, 1 fig.

⁵ "Beobachtungen über die erste Anlage einer neuen Kolonie von *Atta cephalotes*," *C. R. 6me Congr. Internat. Zool.*, Berne, 1905, pp. 457-458, and "Myrmecologische Mitteilung das Wachsen des Pilzgärtens bei *Atta cephalotes* betreffend," *ibid.*, pp. 508-509.

⁶ "Ueber die Koloniengründung bei *Atta sexdens*," *Biol. Centralbl.*, XXV., 1905, pp. 606-619, 625-635, 26 figs.

by workers of an alien species. This is the case with many queen ants that have lost the power of establishing colonies unaided. Third, the queen must always be adopted by an alien species. This is the case in certain ants, especially in the highly parasitic forms that have lost their worker caste. The three conditions here enumerated clearly represent the transition from parasitism of the queen on the same, to parasitism on an alien species. The latter alone is commonly regarded as true parasitism, but the former, which, of course, can occur only among social organisms or during social stages in the lives of solitary organisms, is parasitism in every essential particular. It is not confined to ants and other social insects, but has analogies also in human societies (trusts, "grafters," criminal and ecclesiastical organizations) and in human families (when the parents become senile).

Ant colonies are such closed and exclusive societies that the adoption of strange queens, even of the same species but from alien colonies, usually meets with insuperable opposition on the part of the workers, and, as a rule, female ants have to overcome even greater hostility when they seek adoption in colonies of alien species. There are, nevertheless, at least three different methods of overcoming this hostility and of effecting an adoption. These may be taken to characterize three different forms of social parasitism, as follows:

1. *Temporary Social Parasitism*.—I have given this name to a form of parasitism which I first observed in our American *Formica difficilis* var. *consocians*.¹ The fertilized female of this ant, quite unable to found a colony unaided, enters a colony of *F. schaufussi* var. *incerta* and is adopted with surprising facility. The queen of the latter species disappears, in some manner hitherto unknown, and the *consocians* brood is reared by the *incerta* workers, which, after functioning as nurses, gradually die off and leave a pure *consocians* colony thenceforth able to wax large and lead an independent and aggressive existence. This interesting type of parasitism occurs in most, if not all, *Formicæ* of the *exsecta* and *rufa* groups, both in America and in Europe, in a Myrmicine ant, *Aphænogaster tennesseensis* (parasitic on *A. fulva*) and in a Dolichoderine ant, *Bothriomyrmex meridionalis* (parasitic on *Tapinoma erraticum*). The females of these parasitic species tend to become greatly reduced in size (*F. difficilis* and several allied species: *F. dakotensis*, *microgyna*, *impexa*, *nepticula*, *suecica*, etc.) or at any rate to become smaller than the queens of their host species (*F. truncicola*, *wasmanni*, *oreas*, *ciliata*, *crinita*, *pressilabris*, etc.). This is clearly an adaptation to a mode of life for which an endowment of fat and vigorous muscle is not needed, since these various queens do not have to starve for weeks or even months while bringing up a brood

¹"A New Type of Social Parasitism Among Ants," *Bull. Am. Mus. Nat. Hist.*, XX., 1904, pp. 347-375.

of workers, as in the case of most ants. Santschi has recently made the illuminating discovery that the queen *Bothriomyrmex*, after entering the nest of *Tapinoma*, actually decapitates the queen of the host species and is adopted in her stead. In the other cases the disappearance of the host queen has not been accounted for. In the case of *F. incerta* it is conceivable that she may be ejected from the colony or be killed by her own workers as in the colonies of the Algerian *Monomorium salomonis* infested with *Wheeleriella*, a case to be considered presently. For the *consocians* type of social parasitism Santschi⁸ has suggested the name "tutelary" parasitism, because the young of this species are reared by workers older than the parasitic queen.

2. *Slavery, or Dulosis*.—In this case, as I have shown for the American *F. sanguinea*,⁹ the female enters a *Formica* colony belonging to some variety of the *F. fusca* or *schaufussi* group, kills or puts to flight the workers that attack her and hastily appropriates a number of worker larvæ or cocoons. These she carefully guards till they hatch, when she is surrounded by a loyal brood—of an alien species, to be sure, but nevertheless both able and inclined to bring up her brood when it appears. This is "pupillary" parasitism, to use Santschi's term, since the nurses, or host ants, are younger than the parasitic queen. In this case the queen of the host species is probably put to flight at the time the *sanguinea* queen enters the nest. *Polyergus rufescens* colonies are, perhaps, founded in the same manner, but unequivocal observations on the queens of this species are still lacking. Not only is slavery, at least as manifested in *sanguinea*, distinguished from the other forms of social parasitism by the aggressive behavior of the queen, but also by a peculiarity of her own workers. These inherit from their mother the instinct to enter nests of the host species, and appropriate the young, but these queen instincts are intimately associated with the feeding instincts of the workers, as the latter forage in companies like so many nondulotic ants and consume many of the captured pupæ. Hence the futility of all attempts, like those of Darwin and Wasmann, to understand slavery from a study of the behavior of the workers alone.

Wasmann¹⁰ and Santschi believe that slavery has arisen from temporary parasitism, but although I myself first advanced this opinion, I have been compelled to abandon it. Wasmann found that a colony of *Formica truncicola*, which he has shown to be a temporary social para-

⁸"A Propos des Mœurs Parasitiques Temporaires des Fourmis du Genre *Bothriomyrmex*," *Ann. Soc. Entom. France*, 1906, pp. 363-392.

⁹"On the Founding of Colonies by Queen Ants, with Special Reference to the Parasitic and Slave-making Species," *Bull. Am. Mus. Nat. Hist.*, XXII., 1906, pp. 33-105, pls. VIII.-XIV.

¹⁰"Ursprung und Entwicklung der Sklaverei bei den Ameisen," *Biol. Centralbl.*, XXV., 1905, pp. 117-127, 129-144, 161-169, 193-216, 256-270, 273-292.

site in all essential respects like *F. consocians*, would accept and rear *fusca* pupæ placed in the nest. This, however, is not dulosis. In order to establish his case he would have to prove that the *truncicola* workers can also make periodical forays on *fusca* for the sake of capturing their young, and there is no more evidence that *truncicola* can do this than there is of similar behavior on the part of *consocians*. Santschi, if I understand him correctly, believes that the *sanguinea* colony restricts its forays to the scattered fragments of the original *fusca* colony from which the queen secured her first supply of auxiliaries, and that the slave-making expeditions cease when these fragments are exhausted. This assumption seems to explain the fact that old *sanguinea* colonies are sometimes slaveless and pure, like the adult colonies of *consocians*, *truncicola*, etc. It is, however, rendered highly improbable by the fact that both in Europe and in North America *sanguinea* colonies not infrequently contain slaves of two or more different species or varieties. There is also some evidence that the same colony may have slaves of different species at different times. Professor Forel recently showed me near Morges, Switzerland, a colony of *Polyergus* which in 1904 contained only *F. rufibarbis*, but during the current year contained only *F. glebaria*. The similarity between old *sanguinea* colonies and adult colonies of temporary parasites like *F. consocians*, is more probably the result of two very different processes: in the former case of a languishing or lapsing of the slave-making instincts with age, in the latter, as I have shown, of a gradual extinction of the tutelary workers.

3. *Permanent Social Parasitism*.—This occurs in the following rare and monotypic Myrmicine ants: the European *Anergates atratulus*, parasitic on *Tetramorium cæspitum*, the Tunisian *Wheeleriella santschii*, parasitic on *Monomorium salomonis*, the North American *Epæcus pergandei* (on *Monomorium minutum* var. *minimum*), *Sympheidole elecebra* (on *Pheidole ceres*) and *Epipheidole inquilina* (on *Ph. pilifera coloradensis*). All these parasites are unique among ants in lacking a worker caste, so that they are compelled to live permanently with their respective host species. Santschi¹¹ has recently shown that the just-fecundated queen of *Wheeleriella* enters a *Monomorium* colony and is adopted by the workers, which then actually proceed to kill their own queen. The same conditions probably obtain also in the other cases, as the parasitic queens are too feeble to assassinate the host queen after the manner of *Bothriomyrmex*. In *Anergates* the degeneration of the species as a result of permanent parasitism is extreme: the male is reduced to an apterous, pale and anæmic, sluggish, pupa-like creature which mates in the maternal nest with its own sisters (adelphogamy),

¹¹ Forel, "Mœurs des Fourmis Parasites des Genres *Wheeleria* et *Bothriomyrmex*," *Rev. Suisse Zool.*, XIV., 1906, pp. 51-69; "Nova Speco Kaj Nova Gentonomo de Formikoj," *Internacia Scienca Revuo*, 4° Jars, 1907, pp. 144, 145.

as Forel has shown, and as I was able to observe during the past June in a large *Anergates-Tetramorium* colony at Vaux, Switzerland. This colony contained upwards of 1,000 winged female *Anergates* and several hundred males. Many of the former, placed on the craters of strange *Tetramorium* nests, entered these at once. The *Tetramorium* workers never killed these females, though they often seized them, carried them some distance from the nest and cast them away. The males, too, were not killed, although they were more forcibly and immediately ejected. This behavior is very suggestive, for *Tetramorium* workers when placed on the craters of strange colonies of their own species are at once pounced upon and killed.

It is not improbable that all three of these derivative types, namely, temporary, permanent and dulotic parasitism, have developed independently out of the primitive adoptive type of colony formation, although the details of this development are still very obscure. I have already given my reasons for believing that slavery did not arise directly from temporary parasitism. Owing to the excessive specialization of the permanent parasites and the loss of the worker caste among these species, it is not so easy to determine whether they have arisen from temporarily parasitic or from dulotic species, for it is conceivable that they may have arisen from either, especially as there are other ants, such as *Strongylognathus* and *Tomognathus*, which combine peculiarities of both of these categories. The species of *Strongylognathus* are peculiar to the palearctic fauna and, like *Anergates*, live with colonies of the extremely abundant and ubiquitous *Tetramorium cæspitum*. The workers and females have sickle-shaped mandibles like *Polyergus*. Two species, *S. rehbinderi* and *S. huberi*, as Forel has shown, still possess vestiges of slave-making instincts. In *S. testaceus*, however, which is the common European form, the workers are greatly reduced in number, showing, as Forel has suggested, that this caste is on the eve of disappearing completely and thus leading to conditions like those of *Anergates* and the other permanent parasites. Wasmann once found a *S. testaceus-Tetramorium* colony containing fertile females of both species, and during the past June Professor Forel and I found a similar colony on the Petit Salève, near Geneva. This colony contained a fertile *Tetramorium* queen. The much smaller *Strongylognathus* queen could not be found, but must have been present, as there were young pupæ of this species in the nest. It is evident in this case, therefore, that the parasitic and host queens manage to live side by side (allometrobiosis of Forel). This condition arose, perhaps, from slavery or temporary parasitism by a suppression on the part of the *Strongylognathus* queen of the instinct to kill or drive away the *Tetramorium* queen.

The genus *Tomognathus* is represented in northern Europe by *T.*

sublævis (parasitic on *Leptothorax acervorum*) and in North America by *T. americanus* (parasitic on *L. curvispinosus*). The former was supposed by Adlerz¹² to have only ergatoid, or worker-like females, but Viehmeyer¹³ has recently found winged females as well, and I had previously shown that such individuals exist in our American form. The workers of both species resemble those of *Polyergus* and *Strongylognathus* in having blunted or obsolete domestic instincts. Adlerz's observations seem to indicate that the European *Tomognathus* may be dulotic, but they do not altogether preclude the possibility of permanent parasitism. As there are no observations on the behavior of the recently fecundated queens, it is impossible to decide whether the form of symbiosis exhibited by these ants arose from dulosis or from temporary parasitism or merely from a condition of xenobiosis like that of the North American *Leptothorax emersoni* or the European *Formicoxenus nitidulus*.¹⁴

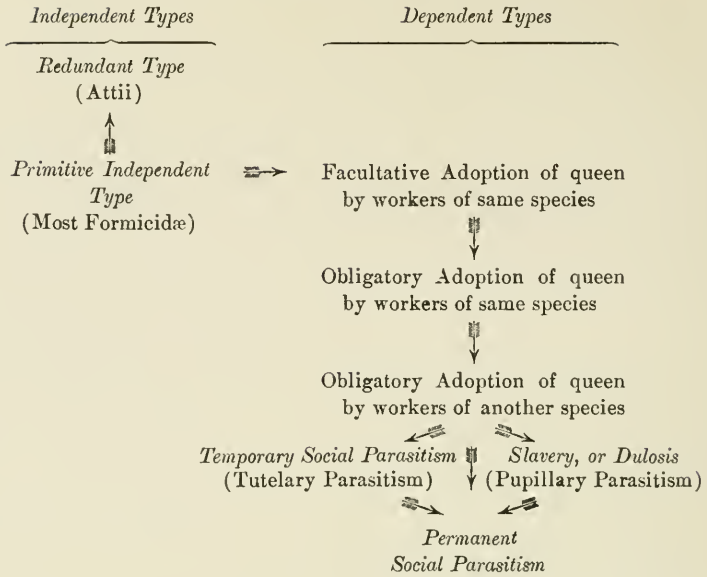
The accompanying diagram will serve to illustrate the phylogenetic relationships of the different types of colony formation among ants as formulated in the preceding paragraphs.

The foregoing discussion shows very clearly that a rational explanation of slavery among ants can be found only by recognizing the phenomenon as a form of parasitism. This conclusion is indeed forced upon us by a comparative study of the various allied forms of social symbiosis, of the ontogeny of the ant-colony, that is, of the way in which it is started and develops, and by a study of the instincts of the queen. We myrmecologists seem to have been hampered in reaching this conclusion by a knowledge of the habits of the queen honey-bee. This insect is peculiar in being permanently and exclusively in the adoptive

¹² "Myrmekologiska Studier—III., *Tomognathus sublævis* Mayr.," *Bih. Svensk. Vet. Akad. Handl.*, XXI., Af. 4, 1896, 77 pp., 1 taf.

¹³ "Beiträge zur Ameisenfauna des Königreiches Sachsen," *Abhandl. naturwiss. Gesell. Isis*, Dresden, 1906, Heft II., pp. 55-69, Taf. III.

¹⁴ Since the manuscript of this article was sent to press I have received from my friend, Mr. H. Viehmeyer, of Dresden, an interesting communication, in which he describes his experiments with a number of naturally dealated and therefore presumably fecundated queens of *Tomognathus sublævis*, *Formica sanguinea*, *Polyergus rufescens* and *F. truncicola*. These queens were introduced into strange colonies belonging to the normal hosts of their respective species. The results obtained with *F. sanguinea* and *truncicola* fully confirmed my observations on the American *sanguinea* and *consocians*. The queens of the typical European *Polyergus rufescens* were much more passive than those of the American subspecies *lucidus*, used in my experiments, and were adopted on the second or third day by the slave species *F. rufibarbis*, but not by *F. fusca* till a much longer period had elapsed. An ergatoid *Tomognathus* queen placed in a colony of *Leptothorax acervorum* "presented the same picture as *sanguinea*. The *Leptothorax* fled with their larvæ and then attacked the queen. During the course of the day, however, the latter managed to kill all of the *Leptothorax*."



or dependent stage, that is, she is unable to found a colony or even to exist apart from workers of her own species. And as the queen ant passes most of her life in similar dependence on her workers, namely, after establishing her colony, the earlier and more characteristic manifestations of her instincts and her marvelous initiative and plasticity were either disregarded or deemed to be of little importance. Attention was concentrated on the worker slave-makers whose activities represent a combination of queen and worker instincts. Darwin was thus led to derive the slave-making from the foraging instincts, and Wasmann—well Wasmann could only keep repeating or implying that the slave-making ants made slaves, because they were endowed with a slave-making instinct—a fine modern example of Molière's famous opium fallacy and of the resources of scholastic methods in zoology! Wasmann supposed that *F. sanguinea* is possessed of an extraordinary fondness for educating the young of the alien *fusca*. This was quite incomprehensible, especially as *sanguinea* workers are in no respect degenerate or dependent on their auxiliaries. Since I have examined many colonies of the European *sanguinea*, which, as a rule, rears much fewer auxiliaries than our American forms of the same species, Wasmann's assumption seems to me to be preposterous. After the habits of our temporary parasites and especially after the behavior of the young *sanguinea* queens had been studied, the relations of the dulotic species to particular hosts were easily understood, for the young queens are reared by workers of a particular host species (*fusca* or *schaufussi* or some of their varieties) or at any rate meet them frequently in the parental

nest. What is more natural, therefore, than that the queens, when ready to establish their colonies, should seek out the nests of these same species? The *sanguinea* workers, too, are reared by auxiliaries of the same species, so that we are not surprised to find that it is against colonies of these that the dulotic expeditions are directed. The absence of any tendency on the part of the *sanguinea* to rear or adopt the males and females of the host species may be due merely to a lack of familiarity of the slave-makers with these sexual forms, which in all probability are characterized by a peculiar odor unlike that of the co-specific workers.

Thus is dissipated much of the mystery with which the subject of slavery has been invested, and the phenomenon becomes intelligible as a form of parasitism in which the slaves are really the host. The dulotic ants differ from the temporary and permanent parasites not only in the peculiarity of the worker instincts, but also as representing parasites with a synthetic host. In other words, the workers, when they snatch the larvæ and pupæ from different nests of one or more varieties of *F. fusca* or *schaufussi*, are actually constructing a unitary colony out of fragments of several colonies of the host species. This peculiarity, as I have shown, arises from the inheritance of female instincts by the workers and a fusion of these with the foraging instincts which the worker slave-makers share with this caste in many other Formicidæ. Santschi expresses a similar opinion when he says: "In fine, slavery reduces itself to a form of pupillary parasitism that perpetuates and extends itself beyond the confines of the nest." His distinction of tutelary and pupillary parasitism is useful, as it calls attention to a more active and a more passive form of this phenomenon, but the distinction should not be overworked. Although the tutelary form would seem to lead more readily to permanent social parasitism with all its attendant degenerative characters, we must remember that *Polyergus*, though very passive in the hands of its slaves, is extremely aggressive when plundering the nests of the host species, whereas species like *F. consocians* and *truncicola*, though very passive in the earliest stages of colony formation, are very aggressive as soon as their colonies have emancipated themselves from the host species. The pupillary and tutelary types are, moreover, already foreshadowed as consecutive ontogenetic stages in the behavior of most ant-queens, for the independent stage in colony formation is pupillary, whereas the closing years of the queen's life are passed in a condition of tutelary parasitism on her own offspring and species.

A TRIP AROUND ICELAND.

BY L. P. GRATACAP

AMERICAN MUSEUM OF NATURAL HISTORY

III

REYKJAVIK was reached; the capital of Iceland, that first old landfall for the anxious vikings, who found that when they threw over their Lares and Penates those undiscerning deities floated ashore upon this inauspicious coast. The choice has a certain pictorial value, but for commercial purposes those old gods should have exercised more discretion, and commercial interests are beginning to weigh overpoweringly in this arctic metropolis. To the immediate north the snow-crowned Esja shines, to the southeast the sturdy eminences of the Lönguhlitharfiáll swim upward over the horizon; and still farther south the volcanic peaks of Krisuvik, where the sulphur quarries are. Then to the northwest like a titanic gleaming gem Snaefells with its ice mantle draws to its overmastering beauty every eye. But this in clear weather, and clear weather is not a very plentiful article in Iceland. In bad weather, which is a trifle more common, the steamers may keep their imprisoned passengers for four days before they can land. The harbor is called so by a pleasant boreal fiction, which is not creditable to Icelandic hospitality. It is expected that next year an appropriation of some \$400,000 will be granted permitting Mr. Smith, the official harbor surveyor of Norway, to execute his *accepted* plans for improving these inclement conditions.

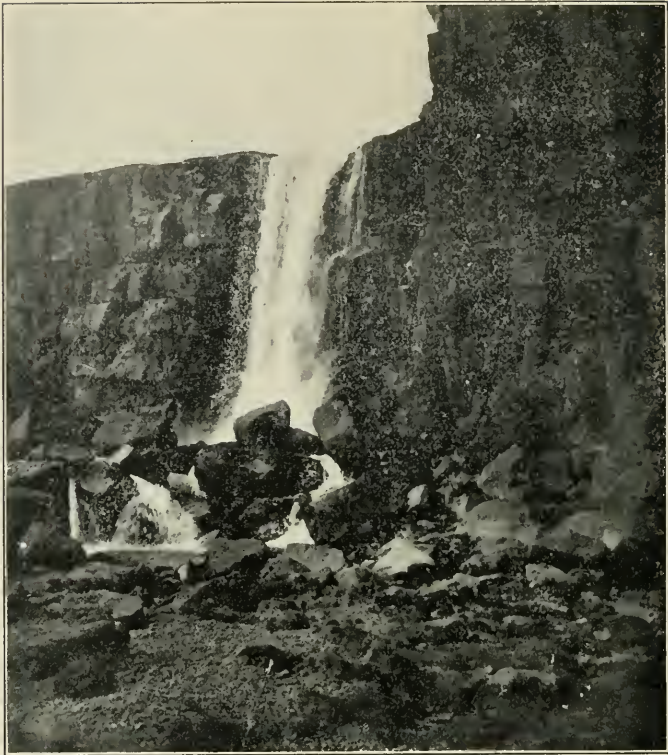
The town of Reykjavik contains about ten thousand inhabitants. It has doubled its size in five years. Stores have developed, and the caravans from the interior can return home laden with the furnishings of a modern household, not omitting wall paintings and bath-tubs. It is scattered over a hilly surface with its more pretentious buildings displayed near the water front and around the square where the statue of Thorwaldsen faces the Althing (Parliament) house. The buildings are of wood (all brought from Denmark, Norway or Scotland), frequently sheathed with corrugated iron, with foundations, in many cases, of concrete blocks. Coals from Scotland are shipped here in great quantities, and the houses are thus provided with comfortable heating equipments. Some of the houses are also stuccoed. At times there is an architectural elaboration noted, but the houses are usually plain and serviceable. Two bank buildings of concrete blocks (the manufacture of these blocks is carried on in Reykjavik) gave its business street a very substantial expression, and two hotels continued



ANSTUR ST., REYKJAVIK.

the agreeable impression that Reykjavik was becoming popular. Photographers are kept busy flattering the vanity of its handsome sons and fair daughters; book-stores supply you with literature of all ages, from "Uncle Tom's Cabin" to the last verses of Thorsteinson; a public library of seventy thousand volumes (in which the *Bulletin of the American Museum of Natural History* may be found) will furnish the visitor with undreamed-of learning, and a cathedral with an organ, a bishop and a choir will save his feet from erring on Sunday; while his incredulous eyes will be shown a public school, a Latin school, a ladies' seminary and a literary club. The last touches of modernity are given in a theater and a jail. Surely those long winter nights, which scarcely leave any day at all, must approach, in the autumn months, shorn of some of their worst terrors. And then there is the coffee house, where coffee, only excelled in Arabia, can be obtained, and languidly sipped to the accompaniment of popular songs on the piano, or in the companionship of garrulous friends. And there is the chess club, which meets on Athalstraeti!

There are two museums in Reykjavik: one a museum of natural history (open one hour a week) and a museum of antiquities—the



THE OXAIA FOSS, THINGVALLIR.

latter over the bank. Both contain admirable specimens and both, it is projected, will be housed with the library in a new public building, where room will be provided ample enough to make these three "foundations" an ornament to the city.

The museum of antiquities has unquestionable importance. Here are very old altar pieces (Christianity was introduced into Iceland in 1000), old vestments and church paintings, with strange archaic buckles, girdles of brass, silver and gold, rugs, carved boxes, old cabinets, swords (many of them strips of iron rust), poignards, stone pestles and mortars, saddles, bits and bridles, lamps and chairs.

The crowning group of objects is a collection of most curious hand mangles, or rollers, for linen fabrics. These "rullur" are made of wood and most elaborately carved, having one uniform form but differing in size and in ornamentation. Some, two and a half feet long, are covered from end to end with carvings, not grotesque, but simple, and rudely or quaintly symbolic and decorative. Glyptic skill has been characteristic in Iceland. I saw some excellent modern examples in snuff horns made from ivory, with carved *motifs* taken from the Icelandic mythology. It seems probable that this ability prevailed more



ALMANNAJA WALL AND ROAD.

in the past than to-day, and may have developed as a recreative feature in the long periods of isolation and idleness. Examples of this old art are difficult to get, and high prices are paid for authentic specimens.

I obtained an antique lamp, in hammered brass from Olafur Sveinsson, the goldsmith and jeweler (5 Austur St., Reykjavik), who deals in every variety of Icelandic curiosities, including belts, brooches, head-dresses, mantles, snuff boxes, bed boards, buttons, bracelets, drinking horns, etc. I paid about four dollars for my little fish-oil lamp and prize it greatly.

From Reykjavik the excursions into the interior are most usually made, though, as I described in a former number, they may begin from the east or northern ports. But the guides and ponies come from Reykjavik and are sent overland. The preparations for a long sojourn in the interior are formidable, especially when the trip contemplated is beyond the zone of habitation and brings the traveller into the tenantless tracts of the middle island. I had no such ambitions or expensive schemes to consider. The ponies represent the vehicle of transport, and none to the accomplished rider could be more acceptable. Their endurance is phenomenal. Two are allotted to each rider, in order to



ALMANNAJA, ASCENDING ROAD BETWEEN WALLS.

change animals. Halts are frequent, where the ponies are considerably treated, and where pasturage is attractive. The ponies feed a little, are remounted, and the journey is continued. Pack ponies carry provisions, clothing and outfit. The guides are unusually intelligent men, many of them teachers during the winter, and are resolute, capable, resourceful and *safe*. They speak English and can thread the devious trails with certainty. In many instances local guides are necessary, as in the crossing of the more difficult rivers.

At last my arrangements were completed, and, with some hastily and not very discerningly purchased "canned goods" (they were English and Danish preparations), and some oil-skin clothes and a pair of loaned water-tight boots, my small cavalcade of fine ponies departed for Thingvallir, up Austur street, bound for the distant Gullfoss. As a most unpractised horseman, I had felt apprehensive about my appearance on one of these jogging ponies, and from the ill-concealed mirth amongst the old women on their way to the public laundry on the outskirts of the town, my worst suspicions were justified. On my return to Reykjavik eight days later, I feel no compunctions in stating, I was unnoticed, an excellent testimonial to my improved horseman-



CAIRNS, TO MARK PATHS IN THE WINTER SNOWS.

ship. The easy and instantaneous control over these active animals by the Icelander is admirable. They are all excellent riders, and with bare back or saddle and stirrups shoot over rock-strewn fields with confidence. These ponies are most gregarious and mine would whinny dismally when left far behind by my precipitate companion.

The road to Thingvallir from Reykjavik is excellent, and in places is receiving reinforcement by stone blocks and gutters. It runs for twenty-eight miles (seven Danish miles) and can be used by bicycles and vehicles. Traveling in Iceland is slowly undergoing helpful transformations; the discomforts and, in a measure, the perils diminish with the introduction of roads and bridges though this need not discourage any one who is looking for adventure. The *jökull*s will certainly repel coercion, and many of the rivers at their periods of transporting rage throw off the yoke of bridges. Let the young men, who wish adventure and exposure, suffer from no qualms of disappointment over the disappearance of either from Iceland.

The region first encountered was a hummocky moorland with stony tracts and distant encircling mountain ranges. It grew rapidly more wild and interesting. We reviewed a rolling country with distant hills, near-by vales and valleys, and breezy brows of rising land—an austere,



THE ALMANNAJA.

lonely country, full of light, and swept over by cold winds. Then out again we galloped over more spacious areas with intermediate black scoriaceous hills, and here and there in green valleys a farm house. There were lakes and morassy heavily-bedded depressions about us with stony sheets of rubble and wind-swept acres of upland, in which we saw grouse and plover, the latter in numbers. An occasional raven croaked ominously, or protesting curlews whistled at our feet. There were many verdant spots and many more barren ones with the distant snow-covered ranges always in sight. The Thingvallir plain is a remarkably undulating or rather abruptly hilly amphitheater with a rising and falling road.

At last, after a passage across a breezy divide, we came in sight of the great *vatn* or lake of Thingvallir. From this point on the journey gained more and more in interest, and crossing dried-up or running stream-beds, and under high banks, with the mountains, beyond the lake, looming up with peaked summits and snow-gullies, with the occasional appearance of a green oasis about some farmhouse, we drew nearer and nearer to our destination, I with great relief, by reason of a badly bruised and suffering body.

The little red-roofed church, distinguished far off amongst its



CHASM AT THE LOGBERG.

gray and green fields, was seen close at hand, the road began a descent, and, in an instant, the portentous gateway of the *Almannaja*, like an Egyptian façade loomed gloomily in our path. We moved slowly—awed into temporary silence—down the gradually sloping road between the frowning walls, over a bridge spanning a brawling torrent by a clear, deep pool, and before us, on a ragged plain, which held a fortuitous sort of herbage, fighting its way against the discouragements of a stony soil, was the *Walhalla Hotel*. To me, at least, it assumed all the radiance of that mythical paradise.

The next day was brilliantly clear, and we studied our locality. It presented a wonderful geological phenomenon. It was a broad valley of depression, between mountains, rifted by long parallel chasms, which crossed it in the direction of its longer diameter, and which were easily descried from a considerable distance, by the furrows they presented in the landscape, by reason of the unequal elevation of their bounding walls. There were some eight of these remarkable fissures—the sundered seams in one vast flooring of erupted rock—and many of them, as that one in which the ancient *Logberg* stood, contained softly flowing streams of water.



WILBUR OTIS ATWATER,

Late Professor of Chemistry in Wesleyan University, who attained eminence for his investigations in metamerism and with the respiration calorimeter.

THE PROGRESS OF SCIENCE

THE RISE IN PRICES AND THE SALARIES OF SCIENTIFIC MEN

THE extraordinary rise in prices which has occurred in the course of the past ten years—amounting to about fifty per cent. according to the index numbers of the *Economist*—is a serious matter for those who are dependent on fixed salaries, as is the case with most scientific men. It is also an obstacle in the way of the advance of science. Those who should be engaged in scientific research may be compelled to give part of their time to securing the incomes that are needed; some may be diverted altogether from the scientific career, while others may hesitate to enter it. There has always been a kind of panmixia among scientific workers, a lack of severe selection of the most fit. The number of those in this country who have undertaken scientific work does not considerably exceed five thousand, and those who do not prove competent to do work of value are likely to retain their positions in institutions of learning or in the government service. Should there be a negative natural selection drawing the ablest men away from a scientific career, it would be a serious matter, the future of our civilization depending largely on the comparatively small group of scientific men.

It is a curious fact that it is largely scientific discovery that has lessened the incomes of scientific men. Prices depend on all sorts of conditions, psychological as well as material, but in the end they are determined by the value of gold and the value of gold depends on the cost of production. The cyanide process and other advances in metallurgy, mining and geology, as well as the discovery of new fields, have greatly lessened the cost of producing

gold. The world's production of gold in 1896 amounted to 202 million dollars, in 1906 to 400 million dollars, or almost double. Unlike the wheat crop, the annual output of gold is not consumed, and the supply is probably increasing more rapidly than industry and commerce, while at the same time relatively greater use is made of government notes and bank checks. The decreased cost of producing gold tends to make all prices higher, and wages and debts are payable in value less than had been agreed. If the cost of production and the demand for gold should remain constant, there would be an adjustment of the supply; and prices and wages would remain constant on a higher level. But wages reach this level more slowly than most prices, and scientific men and others with fixed salaries suffer. As a matter of fact, both the production of gold and the demand for it will remain subject to great fluctuation, and it seems unfortunate that we can not adopt a more constant standard of value, such as would be obtained by averaging together all staple commodities produced in a series of years, and letting the government issue paper currency payable in these commodities and secured by the property of the nation.

THE MARIA MITCHELL MEMORIAL

MARIA MITCHELL, professor of astronomy at Vassar College from 1865 to 1888, a leader in her science, in the higher education of women and in the movement extending the independence of women, was born in Nantucket in 1818, and was buried there in 1889. The Nantucket Maria Mitchell Association, organized in 1902 purchased at that time Miss Mitchell's birth-



MARIA MITCHELL.



THE MARIA MITCHELL NANTUCKET MEMORIAL.



INTERIOR OF THE MEMORIAL.

place. The building has been fitted up as a center of scientific interest for the community, classes in astronomy being there conducted under the general direction of Miss Cannon, of the Harvard Observatory. This summer Professor Mary W. Whitney, a student of Maria Mitchell and her successor at the Vassar Observatory, spent a week at Nantucket, where she gave lectures and informal talks on Maria Mitchell and recent work in astronomy. It is intended to use the building for natural history as well as astronomy.

In March of the present year a five-inch equatorial telescope, made by Alvan Clark and formerly owned by Miss Mitchell, was given to the association, and it is proposed to build an observatory that will properly house the telescope in a fire-proof building. Efforts to complete this building, to enlarge the equipment and to maintain the work are being made, and those who are interested in the work of Maria Mitchell or in a scientific institution such as is planned for Nantucket are invited to join the association, which they can do by paying one dollar annually or ten dollars as a life member.

SCIENTIFIC ITEMS

WE record with regret the death of Professor Lucien M. Underwood, head of the department of botany of Columbia University; of Dr. Edward Gardiner, of the Marine Biological Laboratory; of M. Maurice Loewy, director of the Paris Observatory, and of Mr. Howard Saunders, the British ornithologist.

A MEMORIAL meeting in honor of the late James Carroll was held by the Johns Hopkins Hospital Historical Club on October 14. Addresses were delivered by Drs. William H. Welch,

Howard A. Kelly and William S. Thayer.—The Geographical Society of Philadelphia will hold a meeting on November 6, in memory of the late Angelo Heilprin, founder of the society.—Friends of the late Walter Frank Raphael Weldon, formerly Linacre professor of comparative anatomy at Oxford, have offered the university a sum of about £1,000 for the foundation of a prize, with a view to perpetuate the memory of Professor Weldon and to encourage biometric science.

THE Royal Society has this year awarded its Davy medal to Dr. E. W. Morley, emeritus professor of chemistry, Western Reserve University, and its Copley medal to Dr. A. A. Michelson, professor of physics, the University of Chicago.—Dr. Richard Wettstein, Ritter von Westerheim, professor of systematic botany at Vienna, has been elected president of the Association of German Men of Science and Physicians for the meeting to be held next year at Cologne.

THE American Association for the Advancement of Science meets at the University of Chicago during convocation week, which this year begins on December 30. Together with the American Association meet the Society of American Naturalists and the special societies devoted to anthropology, botany, chemistry, mathematics, physiology, anatomy, psychology, geography and entomology. It is to be hoped that all who are able will plan to attend this meeting—not only professional men of science, but also readers of this journal who are interested in the progress of science. At the New York meeting last year, there were about 2,000 scientific men in attendance, and there is every reason to believe that the Chicago meeting will be equally important.

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