THE POPULAR SCIENCE MONTHLY

THE POPULAR SCIENCE MONTHLY

EDITED BY

J. McKEEN CATTELL

VOLUME LXXII

JANUARY TO JUNE, 1908

NEW YORK
THE SCIENCE PRESS
1908

Press of
The New Era Printing Company
Lancaster, Pa.

THE POPULAR SCIENCE MONTHLY

JANUARY, 1908

THE INSTITUTE OF FRANCE AND OTHER LEARNED SCIENTIFIC SOCIETIES

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CHICAGO, ILL.

II

Great Educational Institutions in Paris, Literary and Scientific

The College of France

One of the more noted of these institutions is the College of France. This college has filled a large place in French history, and contributed not a little to French culture. It is as flourishing to-day as ever. Its history is interesting. In 1529, yielding to the desire of William Bude, provost of the merchants, a scholar as well as a merchant, and especially fond of Greek, Francis I. began the college by founding two chairs, one for Greek and one for Hebrew. Fearing heresy if such studies as these were encouraged, or even permitted, Noel Buda, syndic of the theological faculty of the University of Paris, sought to dissuade the king from his purpose. In this he signally failed. In 1530 a second chair was added for Hebrew, a second for Greek also and one for mathematics. Not long after this instructors were provided in Latin eloquence, philosophy and medicine. Poor Buda's cup was full. But he was powerless. Charles IX. established a chair of surgery, Henri III. one for Arabic, while Henri IV. added chairs for botany and astronomy and completed, as he thought, the work which Francis I. had so wisely begun. At that time there were about 500 students in the college. Its work, always excellent, remained essentially the same for many years. August 1619, the year the Pilgrims were preparing to leave Holland for America, Louis XIII. laid the corner-stone of a new building, and enriched the course of study by founding fellowships of common law and Syriac. Louis XV. introduced the study of

Institut et le Pont des Arts.

The photographs used in this article were taken by J. Kuhn, 220 rue de Rivoli, Paris.

French literature. Strange to say the leaders of the Revolution did not interfere with the work of the professors of the college, but even increased their pay. They changed the name Royal to National, but otherwise approved and favored the institution. This fact alone is sufficient to indicate the place which it was filling and the affection the people had for it.

It was one of the few institutions in which every one seemed to have confidence. Napoleon added a chair for Turkish, Louis XVIII. one for Sanscrit and one for Chinese. In 1874 a chair was established for instruction in political economy. Since that time other chairs have been added, till it is now possible in this college to receive instruction from competent men in well-nigh every branch of learning.

This college is peculiar in the liberties it grants its students. There are no examinations, no diplomas, no degrees. One listens to such professors as one wishes, comes and goes as one likes. There are no registrations. The more famous the lecturer and the more popular the subject, the larger the audience. Few, save specialists, care for the lectures on Hebrew or Chinese. Those on French literature are the most popular. The largest of the nine lecture halls is then crowded. Women are always present. Those on Latin literature are fairly well attended, as are those on the middle ages, those on esthetics, those on the history of art and those on morals. It was on this last topic that Michelet delivered his famous course and was heard each succeeding year with increased interest. Yet this college with its forty professors, while affording the very best advantages for those earnest and faithful students who are able to appreciate the value of its lectures, is not well suited to the wants of young men and young women who care less for hard work than for personal pleasure. There are two semesters, the first beginning the first week in December, the second the week after Easter. Vacation begins between July 20 and July 30.

The University of Paris

A very different institution is the University of Paris, which, with the colleges grouped around it, like the Navarre and the Sorbonne, has been in the front rank of European universities since the end of the twelfth century. It became prominent, indeed, about the year 1170. It grew out of the schools connected with the churches of Nôtre Dame, St. Geneviève and St. Victor, and for some years the chancellor of Nôtre Dame claimed the right, as the quasi head of the university, to grant its licenses. A charter for a corporation with special privileges was given by Philip Augustus in 1200, and seven years later the students of the university were allowed an ecclesiastical trial. By 1229 the contests between townsmen and students had become so frequent and so bitter that many of the latter went over to

Oxford, where they remained for two years, or till the decision of Pope Gregory IX. so favored the students that they felt it safe to return to Paris. It was in this university that William of Champeaux and Abélard taught. Early in its history there were the four faculties of theology, law, medicine and the arts. In the department of the arts there were as many students as in the other three departments of the university combined. Hence in the "congregation," or board of control, the masters of the arts department had four votes, while each of the other departments had but one each. About 1250, Thomas Aquinas, Alexander Hales and Saint Bonaventura were members of the theological faculty. Their refusal to take the oath of allegiance to the university, on the ground that their obligations were to the church, was the beginning of legislation which continued for seven years and ended only with the decision of the Pope that *mendicants*, or members of orders in the church, should have the same right to teach in the university as the regular masters. The outcome of this struggle was the establishment of several colleges which were grouped around the university, but were in a measure independent of it.

The university was at the height of its fame in the fourteenth and fifteenth centuries. Students flocked to it from every part of Europe. By order of Napoleon it was made in 1808 a part of the University of France, and deprived of the rights it had enjoyed as an independent institution. Since 1898, when the law of 1896 under which fifteen universities in France were recognized and made substantially autonomous, it has regained a good deal of its former authority, although the universities are still to a certain extent under the control of the minister of public instruction. But the government, while providing for the support of the professors, no longer provides new buildings for the universities, equips laboratories, or buys books for the libraries. For these increasing needs, local gifts are expected. In the larger cities these have not failed. The increase in attendance, therefore, has been in the universities belonging to the larger cities. There were in the University of Paris in 1904 nearly 13,000 students. It is now one of the best equipped universities in the world. Its professors are among the most famous in the world. The opportunities it furnishes for study are not surpassed by any university in Germany.

The Sorbonne

The Sorbonne, one of the most noted colleges in existence, was founded by Robert de Sorbon, chaplain of Louis IX., October 21, 1250. His object was to provide for the support of poor young men while in training for service in the church. Although the students had been divided into four nations, Picardy, France, Normandy, England, in the hope and belief that they would aid each other through this closer fellowship, poverty was still pressing. Such a college as the Sorbonne seemed to be needed. For a long time only poor students were admitted to its hospitality, and although the fare it furnished was luxurious in comparison with that which the young men had previously enjoyed, it was scant enough to justify the title the college received of "pauperrima domus." During the reign of Louis 100 scholars were lodged in it. They paid nothing. The house which the king made over to his chaplain for the college once belonged to Jean d'Orléans, and on its site with some additional space the present magnificent buildings stand.

Students in the Sorbonne have always been compelled to work. Even in the thirteenth century three severe examinations were required before one could obtain a bachelor's degree. In order to obtain the right to teach or to be known as doctor, at least ten years' study was necessary. Many theses were written, and their authors subjected to many tests of scholarship. The final examination occupied an entire day, beginning at 6 A.M. and closing at 6 P.M. There was no intermission for food, drink or exercise. Twenty wranglers, relieving each other every half hour, conducted the examination. They made it as difficult as possible and did all in their power to confuse the student.

In 1274 the Sorbonne provided courses in the humanities and philosophy as well as in theology. Its faculty has always been very conservative. It pronounced judgment against Jeanne d'Arc, condemned Luther and reform of every sort, and opposed the philosophy of Descartes. Since the revolution there has been no theological faculty. Instruction has been confined to literature and science. There are schools of law and medicine in the vicinity. The literary and scientific faculties of the university are installed in the buildings of the Sorbonne. Here also are the libraries, both of the university and of the college, numbering altogether about 300,000 volumes.

In 1821 the professors of the university complained that their laboratories were too small and their examination rooms inadequate and dark. It was in this year that the schools of the Sorbonne, which had been closed by the revolution, were reopened. Its property had been taken by the state in 1801. Renting it for a time, the state finally turned it into a lodging house for artists, sculptors, painters, architects and men of letters.

The complaints of the university brought up the question as to the ownership of the property. Was its title in the state or in the university? Legislation was protracted, but a decision rendered in 1852 gave the property to the university. Meanwhile the university faculties continued to ask for more room. There must be, they said, new laboratories for the proper study of chemistry, zoology and physics.

La Sorbonne, Paris.

A government commission, after a careful consideration of the petition of the professors, reported in favor of granting their request. Nothing came from the report. In 1846 there was another commission and another favorable report. Still there was delay. In 1855 a decree for immediate reconstruction of the buildings was passed and a cornerstone of what was supposed would be a new and adequate building was laid with great rejoicings. But nothing more was done till 1871 when there was another commission and another favorable report. Money for rebuilding was not secured till 1885. New and enlarged plans meanwhile had been made, and the work of construction was put into the hands of a young man who had been in the practise of his profession less than five years. But he had been carefully trained both in Paris and in Rome. The cornerstone of the new Sorbonne was laid August 3, 1885, in the presence of Jules Grévy, president of the republic, the minister of public instruction and the faculties of the university. Four years later the edifice was ready for dedication. It had cost 22,000,000 francs. It is a model of its kind, severely simple yet beautiful in its adornments and its harmony. At the dedication on August 5, 1889, there were present President Carnot of the Republic, with the members of his cabinet, the officials of the university, representatives of foreign countries and foreign universities and members of the different academies connected with the institute. For its purpose the building is said to be one of the finest in existence.

INTERIOR OF THE SORBONNE.

In it are installed the faculties of mathematics and natural history, as well as those of literature. Here are their class-rooms and about forty of their laboratories. Other laboratories are in the museum, or in the Jardin des Plantes, the medical school.

The Sorbonne is now a practical school for advanced students. It has been defined as a complex of historical and philological seminaries of scientific mathematical institutes which owe their existence to the initiative of Minister Duruy in 1868, and are designed to supplement the theoretical instruction of the university with experiments and a visible demonstration of the truth of principles laid down in text-books or set forth in the lectures of professors.

The Sorbonne furnishes only a few lectures which are free and open to the public. These are given by men of note not connected with the university, and are on topics of commanding interest either in literature or in science. It is needless to add that these lectures attract many listeners. The training in the Sorbonne is better than ever and is worthy its history and its fame.

The Museum of Natural History

Another of the institutions which is an honor to Paris and to the French people is the Museum of Natural History, or the Jardin des Plantes. It attracts visitors from every part of the world and arranges many profitable courses of study. It was known at first as the Jardin des Plantes, but after the revolution as the Museum of Natural History.

Begun in 1633 as a royal garden, its design was to furnish better opportunities for the study of pharmacy and to preserve rare specimens of flowers and herbs. The garden was in reality founded by the two physicians, Herouard and Guy de la Brosse, in the time of Louis XIII. There was a garden of apothecaries in Paris in the fifteenth century. But one far more extensive than any yet known was desired, one in which botany could be studied with advantage to medical science. The king favored the proposal of Herouard and de la Brosse as early as 1626, but as the faculty of the university opposed it, nothing was done till 1633. The garden was placed under the charge of la Brosse as superintendent, with Herouard as assistant. The latter soon died and his place was taken by Charles Barnard. Salaries were small, yet sufficient to support life. Three demonstrators and an operator in botany were appointed and a small sum of money was set aside for purchases and the payment of extra help. The garden was to contain a sample of all simple and compound drugs. It consisted of twenty-four acres and was situated in the faubourg of St. Victor.

To this garden la Brosse gave his life. He laid out the grounds, planted herbs and trees, formed collections and organized courses of study in botany, chemistry, natural history and astronomy. By 1640 there were 2,560 specimens of plants for examination, all of them valuable. Under Vallot, the successor of la Brosse, the garden suffered, but under the direction of Fagan, a nephew of la Brosse and the chief physician of Louis XIV., it improved. Things went from bad to worse under Chiroc, who cared for nothing but anatomy, but under Dufoy, a real lover of nature, there was a change for the better. He made Buffon his successor, who, from 1739 to 1788 was at the head of affairs and whose ideas of what the garden should be were largely realized. Cuvier followed him. Cuvier came to the garden a poor boy, well educated in the classics, mathematics and literature, but supremely fond of natural history. He was soon made a professor. He studied comparative anatomy and through his contributions to this branch of knowledge gained great honor. He was a professor in the College of France, a member of the French Academy, of the Academy of Inscriptions and Belles Lettres, and of nearly all the learned societies in the world. But he permitted neither honors nor requests from any source whatever, to interrupt his favorite studies. His modest home was in the garden itself, and during his lifetime was the meeting place of most of the more famous scientists of Europe. The house, covered with vines and adorned with a bust, is preserved, and marked as the house of Cuvier.

Through the influence of Bernardine de St. Pierre the convention added a menagerie to the garden, a building for the library and other uses, and completed the amphitheater. In the hall of design provision was made for the study of animals and flowers. Although open to both sexes, the lectures, in botany especially, were more popular with young women than with young men. The menagerie, formed by Louis XIV. and installed in the park at Versailles, amounted to little in the time of Louis XV., and in 1795, when given over to St. Pierre, it was an insignificant affair. Under skilful and intelligent management it grew rapidly. At present it contains more than 1,200 different animals, whose food alone is a very large item of expense. Milne-Edwards was for many years at the head of this menagerie and by his management added very much to its usefulness and its fame. He was succeeded by his equally famous son. The museum is a place for study as well as for the casual examination of attractive specimens. There are two semesters each year, and the courses are so arranged as to parallel those of the College of France and the Sorbonne. The same professors do not teach in successive semesters. Each one of them devotes a portion of the year to research. A special advantage in the instruction given here is that pupils are shown the objects described, and are taught to observe and describe for themselves.

There is a course in which the characteristics of annelids, molluscs and zoophytes are described, another in which attention is directed to the organization, habits, changes and classification of insects, spiders, crustacea, another in which the organization of animals, the physiology and classification of fishes are studied and in which conferences are given on reptiles. In fact, provision is made for instruction in almost every branch of natural history. In the galleries of the museum the rarest specimens are found.

Perhaps the schools of botany are the most important connected with the museum. These were organized by Brogniart, though it is true that the botanical school is older even than the Jardin des Plantes. Women in good King Henry's time had a love for flowers and studied them as well as they could. Jean Robin, a gardener of repute, dealt in choice flowers. He brought some precious seeds and roots from Holland which he refused to sell at any price. Guy Patin failed to obtain them even by stratagem. But la Brosse succeeded where others could not, for he employed Robin's son as a demonstrator in the garden, and thus persuaded the father to part with some of his precious possessions. There are two courses in botany, both under the care of able and eminent men. The garden is so arranged that it is easy even for a visitor to learn the names and species of the plants and flowers which it contains. Instruction is given in paleontology with special reference to the fossils of later geological epochs. There is a course in vegetable physiology as applied to agriculture, one in general physiology, one in physics, one in chemistry and one which was introduced by Cuvier in 1795, in comparative pathology, anatomy and anthropology.

The new zoological galleries, begun in 1882 and opened to the public for use in 1889, were during his life under the care of de Quatrefages.

The museums of geology and mineralogy are very large and complete. In the building in which they are found are the library, the herbarium and the orangery. The museum celebrated its hundredth birthday in 1896. Its treasures are nearly all accessible to the public, although there seems to be a love for destruction on the part of the public against which constant watchfulness is necessary. Eminent as the professors in the museum are in the scientific world, they devote themselves so completely to their studies that in Paris many of their names are unknown.

The Observatory

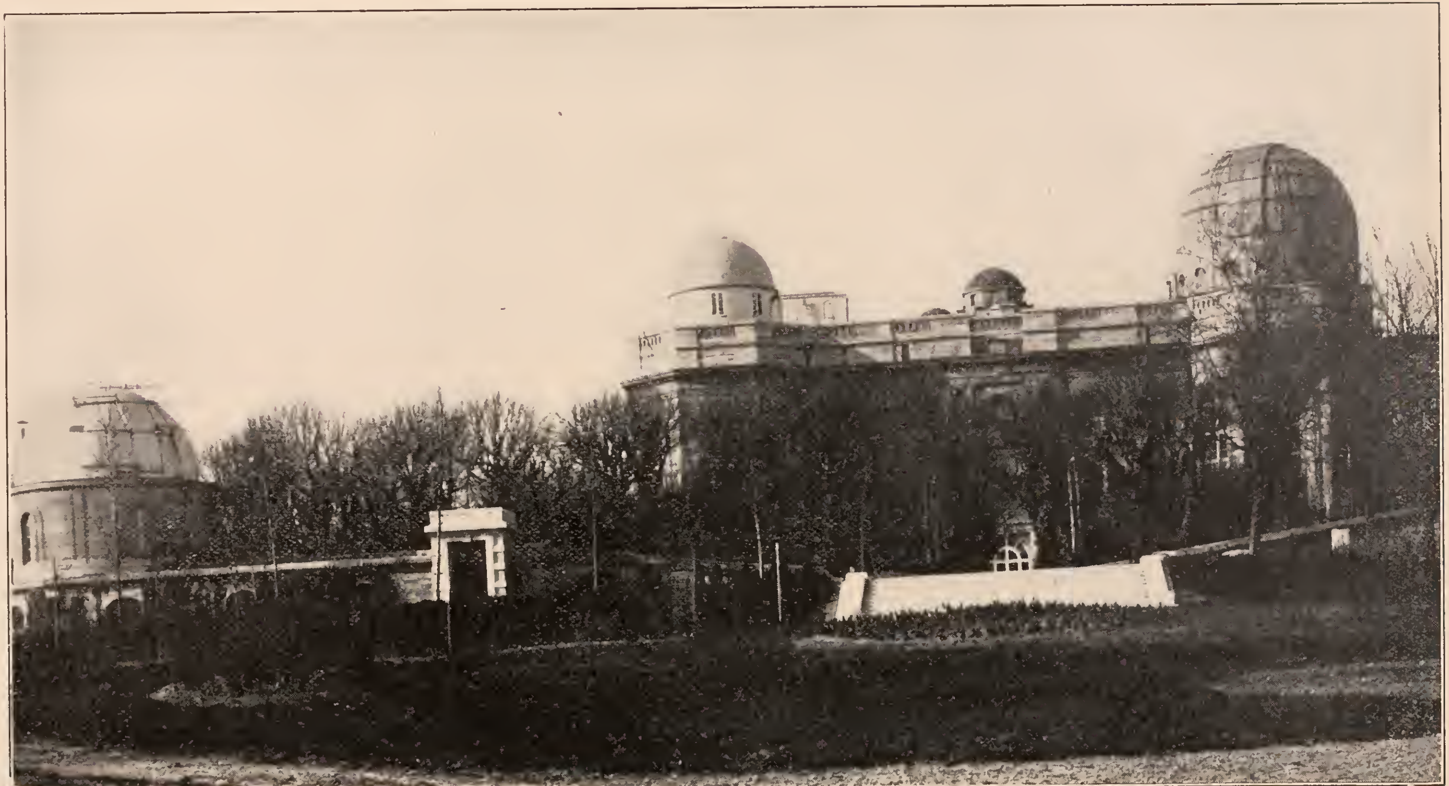
It was to meet the wants of members of the Academy of Sciences, as well as to take the lead in every form of scientific work, that Colbert with the approval of Louis XIV. laid, in 1666, the foundation of what has proved to be one of the best observatories in Europe. A good deal of astronomical work had been done in the previous century: at Cassell, and at Unranienberg, where Tycho Brahe had been stationed and where his observatory late in the century was destroyed by the fury of the people and he himself compelled to flee to Germany for protection. During this century nearly all the observatories were private property and were poorly equipped. In the next century greater interest was taken in astronomy and many of the superstitions connected with its study had passed away.

It was quite natural that Colbert, who was determined that if possible Paris should be the scientific as well as the literary center of Europe, should persuade the king to make generous provision for an observatory and to invite the most eminent astronomers living to make Paris their home. Jeán Dominique Cassini was brought from Italy and with him were associated Frenchmen hardly less eminent than he, Philippe de la Hire and the Abbé Picard.

The observatory was on St. Jacques street over the catacombs, some of which were utilized as laboratories and as lunettes, an object glass being placed at one end and an eye glass at the other. An interesting account has come down to us of a visit of the king to the observatory on May 21, 1682. He was received with becoming honor, and the working of the instruments, in which he seemed deeply interested, was carefully explained to him by Cassini and his associates. The site which members of the Academy of Sciences had selected, June 21, 1667, was an attractive one. It was in the midst of gardens and yet commanded the entire horizon. An attempt was made at that time to fix the meridian line, but this was done more accurately by James Cassini, son of J. D. Cassini, in 1733. Imperfect as were their instruments, large sums of money were expended on them, and excellent work was done. The principal marvels of the heavens were discovered, the sun's rotation on itself, the revolution of Mars, Venus and Jupiter, the nebulæ, variable stars, four of Saturn's satellites and the division of his ring. Cassini's atlas of the heavens of sixty-two pages or plates was graciously accepted by the king as a gift from the astronomer. Huyghens of Holland succeeded Cassini as director of the observatory and he was followed by Roemer, the Dane, who discovered the velocity of light. Although after the death of Colbert in 1683 the resources of the observatory were diminished, the astronomers continued their work and by their discoveries brought fame to the nation. After 1689 and for many years, it is said, their salaries were only one third of what they had been in the time of Colbert.

The work of the astronomers of the seventeenth and eighteenth centuries has sometimes been treated as of small importance. But it was as good as the means for the study of the heavens permitted. The French astronomers, according to the testimony of Airy of England, did the best work in the world. Their efforts to measure accurately a degree of the meridian attracted universal notice. In this work the Abbé Picard was prominent. J. D. Cassini, his son James, Philippe de la Hire and a few others visited India and America to secure favorable observations. In 1755 Godin, Bougner and la Condaminer went to Peru, Maupertuis and Clairvant to Laponie, le Maurier and the Abbé de la Caillet to the Cape of Good Hope. The transit of Venus in 1761 was observed with great eare. The abbé Chappe d'Auteroche went to Tobolsk, Francis Cassini de Maury to Venice, and Pingré to the island of Rodriguez. Observations were also made at San José, California. In 1769 other observations of the transit were made, but war with the English prevented some that might have been very valuable.

In 1770 the condition of the observatory was discouraging. Reports were to the effect that it was dangerous to occupy the buildings. The ministers of Louis XVI. aided J. D. Cassini de Thury in his work. But perfect instruments and promised repairs of the buildings were insufficient to persuade Cassini to remain in Paris after the Revolution and the decree of 1791. In June of this year the convention turned over all the observatories of France to the Bureau of Longitude. Under the influence and direction of such men as Laplace, Delambre, Legendre, Lagrange, Michain, Arago, Bouvard and his son, Mathieu and Mauduis the observatory regained its former reputation and even added to it. Still, as late as 1832, the astronomers found it neither altogether safe nor comfortable to live in the quarters provided for them.



L'Observatoire de Paris.

Since that time the government has been generous. The republic has not been behind the kings in providing the observatory with resources. Its directors have been men of the highest standing in their department, and the work which has been done has been of the utmost importance, unsurpassed by that of any observatory in the world. Equipments are now as good as can anywhere be found. The new building is entirely of stone. The new telescope has an aperture of 1 m. 7.′ Its weight is 10,000 kilograms. For twenty years improvements in buildings and apparatus have constantly been made. It is not probable that the observatory will be moved from Paris, although the site is not the best that could be obtained for all kinds of work. But as there are other observatories in France so that observations which can not be taken in Paris can be taken elsewhere, removal is

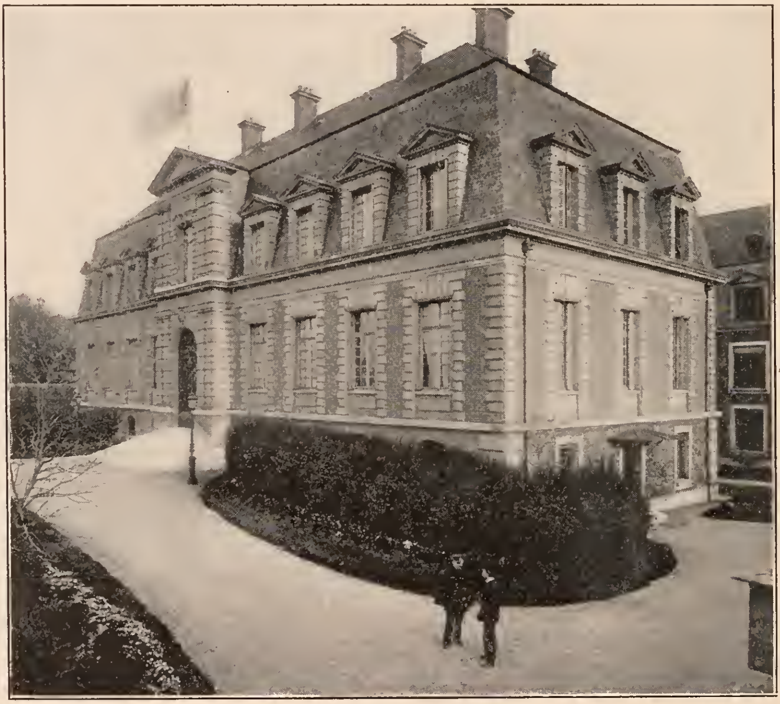
L'Observatoire de Montsouris, Paris

not essential, perhaps not desirable. The establishment for the study of astrophysics is at Meudon and is under the direction of Jansen. Its work is of the highest order.

The Pasteur Institute

Though not altogether a school for scientific research, the Pasteur Institute is one of the most interesting and instructive establishments in Paris. As it is the outgrowth of the energy, skill and devotion of one man, it is fitting that considerable space should be given to his history. Louis Pasteur, the son of a tanner, was born December 27, 1822, at Dole, in the Jura. He began his studies in the college of

Arbois. His father, an old soldier, was anxious that his son should be a professor in a communal college. The young man took a course in philosophy at Besançon, where at eighteen he began to teach. Three years later he had prepared himself for the normal school, but delayed entrance till 1844, in order that he might enter with higher rank. In the normal school he specialized in chemistry, under Balard and De Lafosse of that school, and under Dumas of the Sorbonne. The Sorbonne made him doctor of science in 1847. Leaving the normal school in 1848, he accepted a professorship of physics in the Lycée of Dijon, where he gained fame by his researches into the structure of crystals. In 1854 he was made professor of chemistry at Strasbourg, dean of the

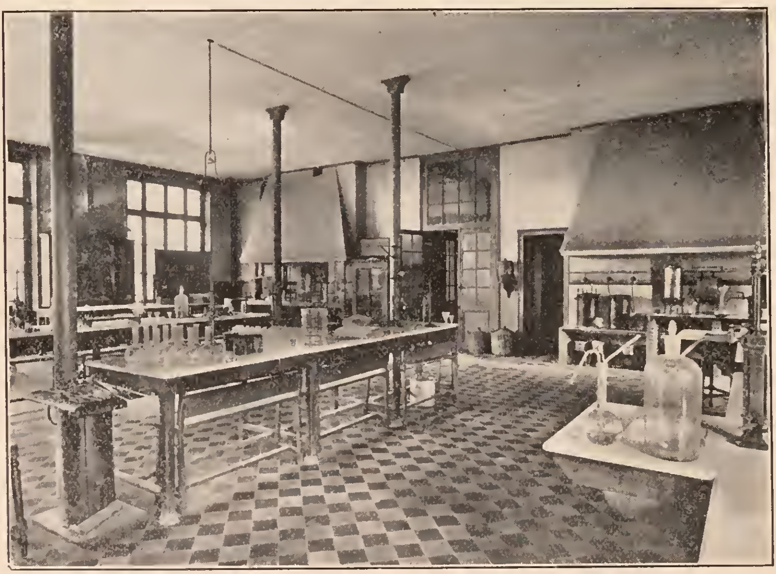


L'Institut Pasteur.

faculty of science of Lille in 1854, director of studies in the normal school in 1857, professor of geology, physics and chemistry in the school of fine arts in 1865, professor of chemistry in the Sorbonne in 1867. These dates indicate the rapidity of his promotion and the nature of his activity. For several years prior to his appointment to a professorship in the Sorbonne, he had studied infusoria and had reached conclusions directly opposed to those held by Pouchet, the director of the Museum of Natural History, at Rouen. Pasteur was confident that infusoria were from germs, or microbes, and that they fixed themselves in substances where they could obtain nourishment. As early as 1854 he had discovered the *ferment lactique,* which causes milk to sour. He studied also what was called the ferment of butter, wine and vinegar, and soon found out a way by which wine could be turned into vinegar with great rapidity. The silk industry in the south of France having been threatened with destruction, a commission was appointed, with Dumas of the Sorbonne at its head, to study conditions, and if possible report a remedy. Dumas sent Pasteur to Arlois, where he remained most of the time from 1865 to 1868. The difficulty was found in the *papillons* and was easily remedied. For some reason not given, he returned in 1871 to Bonn the diploma for a professorship which had been granted him in 1868. From this time he began to turn his knowledge to practical use. Honors came from all quarters. In 1869 he was elected a foreign member of the Royal Society, London. In 1856 he had received the Rumford medal, in 1861 the Jenner prize and in 1874 the Copley medal. In 1872 the London Society of Arts offered him the Albert medal and in 1883 the University of Oxford made him doctor of science. Money also came to him with the expectation that it would be used in the increase of practical knowledge. In recognition of what he had done in saving the silk industry, through the minister of agriculture, Austria-Hungary gave him in 1868 10,000 florins, about $5,000. The Academy of Sciences in Paris received him into membership in 1862, and in 1875 the Academy of Medicine, although he was not a physician, made him a free associate member. The same year a prize of 12,000 francs was given him for his services in promoting industry, and in 1874 the French government voted him a pension of 12,000 francs. In 1881 he was received into the French Academy as one of the Immortals. As early as 1868 he was a commander of the Legion of Honor and was pushed forward as rapidly as possible for the reception of the Grand Cross. Such astonishing recognition could not come except for what the public, as well as scientific men, deemed good reasons. These reasons were his services for humanity. For Pasteur was one of the men whose nature compels them to make practical use of whatever knowledge they gain, whether from books or from experiment. Though men of science had long known something of his ability, his lecture in 1868 on the madness which follows the bite of dogs afflicted with rabies first brought him to the notice of the public. Yet he did not begin the systematic study of rabies till about 1880. He had already found a vaccine for the cure of chicken cholera, and the suggestion had come to him that perhaps the bite of mad dogs might be cured in the same way. Up to 1880 his laboratory had been in the normal school. But in view of what seemed natural to expect from him the municipal council gave him the use of the old garden belonging to the Collège

Rollin, where he kept and experimented upon sick sheep, horses, chickens affected with cholera, mad dogs and guinea-pigs. At the end of five years of study and experiment he was satisfied that his remedies would prove effective for animals, but was skeptical as to their efficacy with men. While in doubt a boy of nine by the name of Meister, from Alsace, was brought to him for treatment. He had been bitten eleven times, and his case was thought hopeless. Drs. Vulpian and Graucher advised Pasteur to try his remedies on him. He might live. He would die unless something was done for him. At about the same time the boy Jupille, who had shown such bravery that the academy had voted him one of its prizes for "Vertu," came to him. Both were cured. Great popular enthusiasm followed. People who had been bitten by mad dogs and who had thought there could be no help for them came every day to the rue d'Ulm where Pasteur was at work. In 1886, of nineteen Russian peasants, several of whom had been bitten in the head, fifteen were cured. Quarters soon became too small. Confident in his remedies, and in himself, Pasteur now appealed to the public for money for a new site, larger buildings and opportunity for more extensive experiments. More than 3,000,000 francs were contributed. The new building, which was very plain, was put up at Vaugrinau, and opened November 11, 1888, with great éclat. The president of the republic was there and with him some of the most distinguished men of the day.

More than one hundred persons every day are inoculated with the healing vaccine. The course of treatment occupies about eighteen



Laboratory of Dr. Roux in the Pasteur Institute.

TOMB OF PASTEUR IN THE PASTEUR INSTITUTE.

days. Those bitten about the head are the most difficult to cure. Yet with all the drawbacks not more than five cases out of every fifteen hundred prove fatal. It is natural that the French people should look upon Pasteur as one of their greatest men and as worthy of the highest honor. It is for this reason that they have responded so freely with their gifts when additional means have been required for the work of the institute. Since Pasteur's death his work has gone forward successfully. One of his pupils, Dr. Roux, has discovered a vaccine which is said to be an almost sure cure for croup and diphtheria. Other physicians are seeking through experiment and special study new and better methods of treating what has hitherto been regarded as fatal disease. It is needless to add that Pasteur's remedy for rabies is now made use of in every civilized country.

The great buildings of the institute are used chiefly for its patients, yet in connection with them places are found for those who wish to study its methods and watch its experiments. A special course of study covering several months is open to all who wish to take it, though those who do take it are expected to pay a small sum for tuition and to meet their personal expenses. Perhaps no establishment in the world has contributed more to the sum total of human happiness than the Pasteur Institute, which is even now only in the beginning of its career.

The Normal School

This article must close with a few words concerning the normal school which is one of the most prominent educational institutions of

Paris, and indeed of the country. The normal school, as its name implies, is for the training of teachers, perhaps it would be better to say for professors in the lyceums, the colleges and the universities not only of Paris, but of France.

Normal schools are of two classes, elementary and higher. The elementary were first established, though not without considerable opposition. At present no one can teach without a certificate from one of them. Instruction is free for those who are accepted as candidates for teachers; oftentimes board and lodging are furnished. From the elementary normal schools, which are the most numerous and of which at least one is found in every department of France, come the men and the women who train the children who are in the primary schools of the nation. The state meets the expense of running these elementary training schools, but the departments are required to provide buildings and the necessary equipments for them.

The higher normal school was organized in 1795. By a decree of November 10, 1903, which went into effect a year later, it was made a part of the University of Paris. The instruction furnished by the university is open to members of the Paris school, to whom many other special advantages are granted. Candidates for entrance into this school are limited in number and are received only after a severe examination. None are received who are under eighteen or over twenty-four years of age. The course extends through three years, and is scientific or literary, as the student at his entrance desires. In consideration of the provision made for his support while in the school, he promises to teach at least ten years after graduation, or to refund the cost of his training. This training is practical as well as theoretical. Each pupil is called upon during his course to exercise his skill as a teacher in giving lessons to his fellow students, and is required to spend some weeks in one of the secondary schools of Paris. Probably there are no schools in the world where more care is taken in the training of teachers than in France and no one of the higher normal schools has done, or is doing, better work than that in Paris. In it some of the ablest men of France have been trained.

THE GRAYLING AT CARIBOU CROSSING

By President DAVID STARR JORDAN

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SAINT AMBROSE, of blessed memory, a fisherman of old, likewise a fisher of men, "magnanimous, plaintive and intense," once declared in his town of Trêves in Gaul, Trêvirorum of the Black Gate, fifteen hundred years ago, that the grayling was "the flower of fishes." This it certainly is, the most choice, the most unhackneyed, of all the prizes of the angler.

The Latin name of the grayling, *Thymallus,* comes from the fact that, when fresh, the fish has the odor of wild thyme, a fragrant mint, common on the brooksides of Northern England. Shakespeare knew on the Avon in Stratford "a bank whereon the wild thyme grows," and I too have found in fragrant Warwickshire many a slope which well answers to Shakespeare's description. But though the grayling is a sweet fish, pleasant to smell as well as to see when it comes forth fresh from the ripple, yet I have never been able to detect the odor the ancients knew so well.

The grayling is cousin to the trout. Its mouth is smaller, its teeth are not so sharp and it has neither the strength nor the speed nor the voracity of the least of the trout. Its scales are larger than in any trout, and there are blue spots as well as black spots on them on a gray background. There is never any red, and from the prevailing gray comes the fine old English name of grayling, as well as the German name of æsch.

The shape of body and fins is like the trout. The little adipose fin is there just the same as in the trout. But the dorsal fin is different. It is much higher than in any trout, and it has more rays. It rises up like a sail and it is marked by sky-blue spots which give the fish a distinguished appearance when it is at home in its native waters.

The grayling lives in swift, clear streams—not often in lakes. It calls for colder water than the trout, and so its range is farther to the north. Indeed, it is comparatively a rare fish outside the Arctic circle.

The different species of grayling are all very much alike in looks as well as in habits. The common grayling of Europe is *Thymallus thymallus.* It ranges through northern England, Scotland, Scandinavia and Russia. There is, likewise, a species of grayling spread all over Siberia, but we know very little about this fish, and are not sure what species it is.

Through the Yukon region of the great northwest, there is a grayling, very abundant in the right waters and bearing the name of the standard-bearer, *Thymallus signifer*. In the old days, after the great glacial ice, this fish extended to the eastward over a much larger area, but the ice has melted away, and there are left three isolated colonies to the southeast of the main band. One of these colonies is called *Thymallus ontariensis* or *tricolor* and lives in certain streams, notably the Jordan and the Au Sable, in the sandy woods of the southern peninsula of Lake Michigan. In both these streams the grayling is growing scarce through the combined evil influence of the lumberman and the trout-hog. In the northern peninsula, there is another isolated little colony. Let us call its stream the Nameless River, and if we leave it so the thyme-scented fish may increase to fill other rivers which are not nameless.

The remaining colony, a little changed from the other two through long isolation, is in Montana, at the head of the Missouri River. The Montana grayling is called *Thymallus montanus*. It is most plentiful in the Gallatin River, and if you look through the mountains till you find Horsethief Creek, you will be sure of at least one day's good sport. It will take all day to find the creek, no matter from where you start.

And this brings me to describe my best day's sport with the grayling. It so happened that in June, 1897, the present writer was in the city of Juneau, the metropolis of Alaska. That day, the Canadian surveyor, Ogilvie, since noted in Klondyke history, had reached Juneau from up the coast and across the mountains with a wonderful story of the happenings in the northwest territory of Canada, on the banks of the middle Yukon. It seems that the Indian Skookum Jim of Caribou Crossing, with his friend Tagish Charley, a squaw man Siwash George, and his wife, who was Skookum Jim's sister, were wandering across the country, supposed vaguely to be in the interest of one Anderson—looking for gold.

Away down the river beyond Lake Labarge, one of the men took sick. He had eaten too much blubber of some sort, and the wife of Siwash George went down to a brook to get him a basin of water. In the bottom of the basin was a streak of fine gold. They went down to the stream and bailed out more. Then Skookum Jim, as his name would indicate, started out swiftly at the top of his speed, "touching only the high places," to record with the Dominion authorities the claim of himself and his associates. Skookum in Chinook means swift, hence Skookum Chuck—a waterfall. Bonanza Creek, Klondyke, Dawson then at once became names and then realities, and all the world knows their story. Skookum Jim, a millionaire, built himself a large house of pine lumber at Caribou Crossing. He went to Seattle to buy a Brussels carpet for its floor. When the carpet came it was too broad by nearly a yard for Skookum Jim's best room. So he had the house cut apart and spread until the room was large enough for the carpet. How Tagish Charley became one of the generous rich, beloved of all men, and how Siwash George deserted the woman who made his fortune for a San Francisco actress, all this, with the spectacular career of Swiftwater Bill, are known to every one in touch with the gossip of the smart set of Caribou Crossing, Seattle, and San Francisco.

When Ogilvie told all this in Juneau, the whole town responded. Juneau itself lay on the very frontier of adventure, and here was something newer and greater and only two thousand miles or so beyond.

So the gamblers and gold seekers, the clerks and lawyers resigned their positions, threw up their jobs, in some way or another made their way to the head of navigation, Dyea or Skagway, and then struck the White Pass Trail. The Bright Eyes Opera Company broke its engagement at Juneau and men and women started over the mountains to Bonanza Creek. And after them came a most wonderful migration—one of those movements which, if anything could, lend "to the sober twilight of the present, the color of romance."

All the way southward, the word went from Juneau. Cigarette young men, who had never done a man's day's work in their lives, crowded the smoking rooms in the Pullman cars, and pampered dogs—St. Bernard, Great Dane, Mastiff, brought up in luxury, and bought or stolen to do the work of a husky or Siberian wolf dog—rode in the baggage cars. Along with the rest came young women and old women, dainty Mercedes, silly, pretty and whimsical, demanding the impossible, elderly graduates of cheap boarding houses with iron hand and iron jaw, capable of making some sort of a way anywhere. All were loaded down with clothing and provisions needed for an Arctic winter. Most knew nothing of hardships, nothing of dogs, nothing of trails over glacial mountains and through endless chains of rock-bound lakes, each hidden in its cleft of rocks. They knew nothing of boats or rafts, or the breaking up of the ice, nothing of gold or men or Alaska. And the dogs were just as ignorant, and had not even seen a map of Alaska, and did not know beforehand that they were going there.

From Skagway—a wild bedlam of incongruous elements, with its hero mayor, chief of the Vigilantes—the trail goes up the boisterous river, through the fir woods, past the mouth of glaciers, into a great amphitheater like that at the foot of the Splügen Pass, then in long zigzags and windings past reckless splashing waterfalls and unbridged chasms to the foot of the moss-covered White Pass. Then up the pass to its gusty Summit Lake and the long ravine-like chain of lakes at the head of the Yukon which may keep one guessing for miles as to the way past or around them.

In a sheltered depression on the summit is a place which should be historic. Here every band of pilgrims has camped for the night. Here it has cast away its luggage, discarded its horses, abandoned its dogs. Into the springy heather-grown basin, sheltered from the wind, we may find trodden into the muck harnesses, sleds, bottles, cups, plates, hats, trousers, neckties, bones of dogs, bones of horses, ravens, newspapers, playing cards, cigarette papers, shirts, collars—every evidence of a failing civilization. The dead ravens tell the story of their premature attacks on dogs and horses, for the men have pistols, and they are the last to go. Near this place, some later humorist has built a house of empty beer bottles, set together with mortar—a house big enough to shelter you and me from the storm. Bones of men are strewn along the way—you can trace the trail by the soiled and dislocated heather—but all these, so far as I know, have had a decent burial. Some of them, to be sure, were buried under avalanches, but that was on the south side of the pass, near the foot of the great unnamed waterfall, over which unheeded flows the Nameless River. We have passed the waterfall and the river, and are now well down on the Yukon side. The little ice-cold Summit Lake, where more than one loaded team and its teamsters went through the breaking ice, is said to be well stocked with trout. Men described these to us as Dolly Varden trout (*Salvelinus malma*). As the lake flows into the Yukon, and as the Dolly Varden is not found in the Yukon, which has only the Great Lake trout or Mackinaw trout (*Cristivomer namaycush*), we developed a geological theory that the Yukon had stolen this lake from the Skagway. The theory looked not unreasonable. Rivers do such things. At the head of the lake was a little dam of glacial drift. Cut through this dam, and the head of the Yukon would flow down into the Skagway. Perhaps it did so in the days before this dam was made. But facts are facts. Let us see what kind of trout lives in the lake, and we will tell you its glacial history. My companion, Professor Harold Heath, borrowed a fly and cast into the lake. We had one rise, and landed the fish. It was the Great Lake trout and not the Dolly Varden. So we laid our theory on the shelf and allowed the Summit Lake to remain in the past as it is in the present, a head-spring of the Yukon. I said that rivers do such things. At the head of the Roanoke River, near Allegheny Springs, in Virginia, is a valley which the Roanoke has stolen—fishes and all—from the Holston River, on the other side of the ridge. To steal a valley is to undermine it gradually from the other side, until the water in the first valley turns and flows the other way. But the Yukon has stolen nothing from the Skagway, and on second thought it deserves no credit for its reticence.

It looks cold to the north of the White Pass, even in midsummer. Down the long rock-ridges between the lakes goes the trail —on and on through reindeer moss and heather, all the way above timber line, down to Lake Linderman, long and narrow, like a gigantic rock-bound ditch of the giants. Down the long shore of Lake Bennett, through scrub and swamp, birch and brambles. No wonder so many took to the ice, rotten though it be in early summer. No wonder so many tried to make rafts of logs, when the wind blew in the right direction. On and on down the straight shore of gusty Lake Bennett, two days' march it may be. Then you come to Caribou Crossing. The caribou is the native reindeer, and here in the interval between Lake Bennett and Lake Tagish, with Lake Marsh beyond, is the only place for 500 miles where a herd of caribou can cross the Yukon River. Let us cross it quickly, too, for the water is very cold, and deeper than a man or a caribou likes to wade. Here at Caribou Crossing lived and worked for a generation Father Bumpus, of blessed memory, bishop of the Yukon. And here still lives his charming wife, born to the soft skies of England and the gentle ways of English society, but here a power for good in the wilderness to which she gave her life. It seems to me that if the Church of England were all-wise, it would some time send his grace, the archbishop of Canterbury, to exchange places for a year with the bishop of Yukon. The bishop of the boundless hills would learn something in Canterbury, no doubt, but consider what the archbishop of Canterbury would learn were the seat of his diocese for a year at Caribou Crossing.

From the Caribou Crossing the river curves through the fir woods to the right—for we are below timber line again. Then it sways forward, running through a couple of lakes into a swift gorge—the famed and fated White Horse Rapids—below which it widens out into the immense Lake Labarge, which runs to the northward as far as the eye can see, and a good deal farther. Some men—about one in ten, perhaps—preferred to take their chances in running the White Horse Rapids, rather than to carry their belongings over the Caribou Hills. Some of these—one in two, perhaps—got through safely. The rest went to swell the romance, the terror, the tragedy of the gold of the Klondyke and the White Pass of the Yukon.

But the Caribou Crossing is full of fish, and some of these—lake trout, cisco, pike, ling, sculpin—take the hook when it is properly baited. You can stand on the little wharf in front of the Bishop's House, or on the bank in Skookum Jim's dooryard and cast for grayling and the grayling will respond. Better than this, you can cross the river and go a couple of miles across the field and around a bayou where the wood begins. In the little forest you will find a roaring brook and at the foot of a cascade you will find the grayling as eager as you are, and, if you are contented with a reasonable basket, you will fish awhile, then lie down on the heather and take for yourself something better than many fishes—that which Wordsworth called the "harvest of the quiet eye."

WHAT IS MATTER?[1]

By Professor S. E. MEZES
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THIS question is at once the earliest and latest to excite scientific curiosity. It was asked at the dawn of science by Thales and Anaxemander, by Heracleitus, the gloomy, and Democritus, the smiling, philosopher. And to-day, with all the resources of modern science at their command, Thomson, Ramsay, Lodge and Rutherford are still asking, What is matter? What is the stuff of which the world is made? The great difference is that at last the solution seems about ready for acceptance, a solution so simple that we must marvel at the denseness of the human wit that so long failed, and in large measure still fails, to recognize it, though it was proclaimed, in dark words to be sure, by Heracleitus in the early fifth century B. C.

There is, of course, no question as to the reality of matter. That has never been seriously doubted. With the problem properly stated, even Bishop Berkeley would not have done so, though unquestionably he thought he did, and many since his day have been misled by his self-deception. Berkeley merely disagreed, rightly, with the common view of what matter is. Matter, he taught in effect, is very different from what the man in the street thinks it to be. And to Berkeley's real doctrine the doughty Dr. Johnson had no answer. By kicking the stone, he reassured himself that matter is real, which needed no proof, but failed to cast the faintest glow of light on what matter is, which is the real question.

Before reflection, all men think they know matter perfectly. Why, they say, matter is the commonest thing in the world; it is everywhere, which is, of course, true. And they are likely to add at that stage, Everything is matter, which is false as matter is ordinarily conceived. But, if you are still unsatisfied and press to be told definitely what matter is, the man in the street is likely to resort to the "when" definition, so dear to childhood, as did Dr. Johnson, that colossal wayfarer. Matter is "when" you kick a stone, or when you see a tree, or eat its fruit, or hear the thunder roll. Now, it goes without saying that matter is in fact there when you do each of these things. But so is much else besides, including yourself, the sorenes of your toe, if you kick hard enough, the color you see, the savor you taste, and the sound you hear. But matter, of course, is not pain, color, taste or sound, any more than it is yourself or any other self. All these experiences of

[1] Presidential address before the Texas Academy of Science, revised and adapted.

ours are there with matter, but matter they simply are not, either singly or all together. Color is with its beauty, in the eye, or rather the mind, of the beholder, and there too is sound with its melody, and all other *experiences*. They are the effects wrought upon us, through the intermediation of our sense organs, *by* matter. Given an adequate outer cause, an eye in its organism to be affected, and a mind to perceive, and color is the result. Given cause, ear and mind, and we have sound; or cause, touch organ and mind, and we have the feeling of hardness. But matter, without sense organs or mind, can not have such experiences. And the substance of matter they are not. We know so much about the total situation when matter is present that we easily delude ourselves into thinking that we know the matter too. But, as Dr. Higgins once said, in dealing with experiences we are merely playing with the pebbles on the beach; the sea of reality, matter itself, is still beyond our ken. What matter is not, its effects on our senses, is plain. But what it is, all such talk leaves as dark as before it was uttered.

And, until recently, science has been as dumb and helpless when confronted by this question, as has common sense. Much is told about the behavior of matter; how fast and far, and when it moves, and what is the result of its impact, etc.; all very interesting and highly useful information. But how anything behaves, what it does, is one thing; what it is is something entirely different. One is reminded of Dr. Johnson's definition of oats, as a grain eaten by men in Scotland and horses in England, except that he does class it as a grain.

Another familiar device of science is to divide and conquer; though in fact dividing does not itself succeed, but merely leads indirectly towards success. "No wonder," says science, "we have not found out what matter is, for matter is very deceptive, and is not at all what it seems. In fact and in truth matter is made up, not of the large bulks we see, but of minute particles, called molecules, in the neighborhood, for the simplest element, hydrogen, of one fifty-millionth of an inch in diameter, and these minute molecules are in turn made up of very much smaller particles, atoms, two to a molecule in some elements, many more than two in others. And observe, we can point out how the atoms are placed in the different molecules, and see how beautifully they shift their places in mystic dance when a chemical reaction occurs. *All* that happens in the intercourse of matter is at bottom but the interplay of atoms and of molecules. How wonderful is nature, and how searching the discoveries of science!"

All of which is true, indeed profoundly useful truth. For has not science transformed the face of the earth in an incredibly short time, a little over fifty years. And yet how much nearer are we to knowing what matter is when we discover how it is put together? If we ask what wood is, and are told that it is made up of tiny pieces of wood put together thus and so, information, important information, it may well be, is given. But plainly our question is not answered, it is merely pushed a step farther back. In the equations of science, it would seem, matter is represented by an x, whose value is seldom sought. But with everything made out of matter, it is certainly worth the while to search out its intrinsic nature.

Possibly then, since common sense and science appear to be equally unable to say what matter is, the problem is beyond the scope of human powers. May be, as Lord Dundreary says, it is one of those things no fellow can tell. It may be so, but it is well to remember that the discoveries of science have nearly all been things that the faint-hearted said no fellow could tell. Besides, as regards the problem of matter, no philosophic generation has ever been wholly agnostic, and the foremost members of the present and latest scientific generation are not agnostic. And, moreover—a point of especial significance—it is well to remind ourselves that philosophers and scientists, in spite of the difference of their points of view, and of their methods, seem rapidly to be approaching agreement as to the nature of matter. It should then repay us to hear what they have to say.

Insisting, as we have seen, that sensations—colors, sounds, tastes and the rest, are not matter, or any part of matter, philosophers—at least those unconfused by Hume's oversophisticated attack on causes, taken so seriously by Kant—these philosophers, I say, maintain that sensations rightly studied tell us what matter is. Known directly, and indirectly as effects of matter working on our senses, sensations, critically considered, show matter to be a vastly complicated system of active causes, occupying space, that and nothing more.[2] Each material object is thus known to be a group of forces, more or less complicated in their interplay, and varied as to their constituent elements. The forces constituting a living cell are very varied in kind and complicated in interplay, as compared with those composing an equal volume of hydrogen gas; but complicated and varied forces are forces none the less. Moreover, all kinds of matter have one quality in common, the forceful defense of the space they occupy. This is called their solidity or impenetrability. Everything material opposes force to attempted encroachment on its space, and, unless given room elsewhere, absolutely prevents its entire appropriation; though all the forces of the universe pressed upon a single drop of water, it could not be annihilated. Thus impenetrability is the active defense of space. The fundamental constituent of matter is force.[3] And other constituents are the chemical, electrical and remaining physical activities, whose

[2] Nothing more so far as sensations of the special senses can help us to know the intrinsic nature of matter.

[3] Some would prefer the term "energy," others "activity." I know of no satisfactory term; but the thing denoted is *real*, many and baffling as are the mysteries it contains.

effects are more or less familiar. Nor need philosophers deny that matter is made up of molecules and atoms, or of electrons even, provided always these smaller and smaller particles are admitted to be bundles of forces, occupying less and less extended allotments of space.

Where this view departs from that of common sense, it is simpler, that is all. Common sense says matter is blue, sweet, soft, etc. No, say the philosophers, these are effects, not properties. Again, common sense says, and here with a shrill insistence, Force is not matter, but in it. No, say philosophers, there is no need of complicating with an irrelevant distinction. Force, activity, achievement, that is all there is to matter. As Heracleitus said 2,500 years ago, παντα ρει, flowing, change, *doing* is all.

Beyond question the blind force of our nature strongly inclines us to ask for more. But in obeying this prompting we are but worshipping an idol of the tribe, a fallacy patent enough as soon as the nature of the mind is understood. The insistence on something more than force in outer objects registers the triumph of the "imagination," a blind "faculty," as Kant rightly called it, unaware of its own contents and of their significance, over clear-sighted and self-critical reason. Everything we talk of and think about, including matter, is identified, when necessary, and mentally dealt with, by means of its picture stored away in the imagination, which picture appears automatically when its aid is required. Without such counterfeit presentments the mind could not make a beginning of dealing with the objects about it, for their names are not pasted upon them, and besides, the mind is often concerned with them during their absence, and must then have a representative with which to treat. Now, most men picture matter chiefly in visual terms, though partly in terms of touch and muscular feelings, which last are so constantly aroused by the resistance of things. And the fallacy consists in clinging to the picture of matter, naïvely, uncritically, inaccurately construed before reflection, out of our most familiar sensations, and in insisting that it correctly represents matter, although reason clearly demonstrates that sensations are no parts of matter, but only its effects. And the fallacy continues to impose on us because the picture works in subconsciousness, automatically registering dissatisfaction with force, as failing to fill out its notion of what matter is. As soon as we know that the picture of our imagination is formed during the early unthinking days of our ignorance, we know that it has no proper standing as against the critically tested conclusions of reason. But that does not check the dissatisfaction automatically suggested by the imagination, which philosophers feel in common with other men. The difference is that they disregard the feeling; they refuse to bow down to this idol of the tribe.

The same dynamic view of matter is reached by another avenue of approach, as is pointed out by students of the evolution of mind.

Probably the contribution of evolutionary theory to our knowledge of mind that bulks larger than any other is the discovery, growing clearer with each year of study, that the human mind also is fundamentally just a group of activities, greatly complicated, mysteriously unified, wonderfully resourceful, marvelously progressive, self-conscious, moreover, and free, and yet at bottom a system of activities, no more. Activity, doing, will, that is the core of us, the rest, sensation, feeling, idea, they are but the effects of our own or of other activities. A spirit, in etymology, is just the active principle of a liquid: and activity is what distinguishes the quick from the dead. Even superman, in his ascending excellence, we must believe to be but vaster and more skillfully and perfectly ordered activity. And man is distinguished from his humbler brethren, and higher animals from lower, by what they can do. Man hesitates, chooses, plans, contrives and fits things together in fulfilment of his purposes. As we descend the animal scale these activities first diminish, and then disappear, dull routine taking their place. But this implies, not a substitute for activity, merely its simplification. And the same decrease of complexity obtains as the transition is made from animals to plants, and from plants to inorganic matter. This no doubt seems a hard saying to those who have not followed discoveries and discussions in this field; but to those who have it is little more than a commonplace. We do not yet know how inorganic activities become systematized into organic, or what determines their form as vegetable or animal. The cell still keeps its secret. But that inorganic is transformed into organic is plainly shown by every breath taken, every meal eaten, and every development of an embryo to maturity, as the reverse transition is shown by all waste processes, including death itself. As men organize themselves into states, and lesser associations, which have organs and modes of activity which no man has, so, it would seem, molecules organize themselves into cells, and cells into living beings, which differ even more in structure and function from the units composing them.

In substance, then, comparative psychology teaches that a man is a complicated system of activities, sensitive and conscious; an animal a less complicated system, sensitive and conscious; a plant a still less complicated system, sensitive, but only dimly conscious, if at all so; and organic matter, the simplest system of activities we know, whether either sensitive or conscious we are not yet prepared to say. So much is quite plain. But all is not said. It is also plain that inorganic, or so-called dead matter, has, in the way of evolution, developed into organic or living matter, and that matter is being daily transformed into living, yes, into conscious, beings, and living and even conscious beings are being daily transformed back into mere matter. These plain facts of themselves throw not a little light on the nature of matter. For they show that the constitution and the nature of matter must be such as to allow of the development and interchange discovered. Matter can not be very dead, it can not be blankly non-conscious, it would seem, if everywhere and at all times it is, in the ordinary routine of the world, nourishing and stimulating life and consciousness, which in their turn dissolve into mere matter in the same normal way.

Such, too briefly and imperfectly stated, are the contributions of philosophy, and its component and ancillary sciences, to our knowledge of matter. Next we turn to the physical sciences themselves, physics, chemistry and new-born chemico-physics, and find, as will presently appear, a singularly impressive confirmation of the results set forth. This should not surprise us. It merely adds one more to the many instances where philosophy's reasoned conclusions have proved prophetic of the more concretely reached results of experimental science. The former, glancing over the promised land throughout its broad extent, spies out its prominent landmarks, and sets them up as goals to guide the slow and laborious but sure occupation which it falls to the lot of the latter to undertake. Each task yields its own delights, and each performs its peculiar service. Where both are indispensable, only the cramped mind will seek to belittle either.

Nearly two and a half centuries ago, in 1658, to be accurate, Boscovich, the great Italian administrator, diplomat and physicist, set forth and ably defended the view that atoms are but forces, each concentrated in a mathematical point, and held apart by their mutual repulsions. The view did not fail of its adherents, numbering among them names as great as that of Faraday. But even if the prejudices of an imaginative race had allowed it a fair hearing, which they did not, the state of science was not ripe for the general acceptance of the theory. Electricity did not exist for science, and countless hours of research had still to be labored through before a sufficient weight of experimental facts could be accumulated to outbalance our tribal idol. So stiff-necked is an inborn bent of human nature. Besides, Boscovich delayed the triumph of his theory, in its essential principle, in my judgment, by confining his force atoms to mathematical points, and denying them spatial occupancy, the fundamental attribute of matter: a course the more to be regretted, as the denial is unnecessary, indeed contrary to plain experience.

The status of Boscovich's theory, and its more or less modified successors, remained practically unchanged till the end of the nineteenth and the marvelous beginning years of the present century, a few of the best minds of each generation upholding it, but the large majority of physical scientists, including men of unsurpassed eminence, according it a neglect more or less contemptuous. But these recent years have been bringing about a change. A number of physicists of the first rank are aggressively championing the dynamic theory of matter, and as each unexpected discovery, hurrying upon the heels of its predecessor, brings support to the theory, its opponents seem conscious of engaging in a losing fight.

Before passing to the chief evidence, I will just mention some curious experiments of the Hindu physicist, Dr. Bose, a professor in Calcutta University, which indicate the trend of the more advanced research that is now being prosecuted, and indirectly support the dynamic theory, by tending to show that metals, at least, are not dead, but alive, bundles of activities like living animals. Dr. Bose's book, "The Response of Matter," I have not been able to secure; the quotation that follows is from a notice of it in the London *Review of Reviews*. Dr. Bose's discovery is, that stimulated metals give back, under proper conditions of observation, the electric response that has been thought peculiar to, and characteristic of, organic or living matter, and, with variation of conditions, vary their response just as organic matter does:

> When the metals were stimulated by a pinch they also made their autographic records by electric twitches, and thus, being responsive, showed that they could in no sense be called "dead"! Nay, more, it was found that given the records for living muscle, nerves and metals, it was impossible to distinguish one record from another. For the metals also, when continuously excited, showed gradual fatigue; as with ourselves, so with them, a period of repose revived their power of response—even a tepid bath was found helpful in renewing vigor; freezing brought on cold torpidity, and too great a rise of temperature brought heat rigor. . . .
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> Death can be hastened by poison. Then can the metals be poisoned? In answer to this was shown the most astonishing part of Professor Bose's experiments. A piece of metal which was exhibiting electric twitches was poisoned; it seemed to pass through an electric spasm, and at once the signs of its activity grew feebler, till it became rigid. A dose of some antidote was next applied; the substance began slowly to revive, and after a while gave its normal response once more.

But it is not upon such experimental curiosities that the dynamic theory of matter is based, significant as they may be of the future discoveries of science. It is more substantially founded upon the evidence of the spectroscope, the fast-growing knowledge of electricity, and the marvelous results of the experiments on radio-active substances. Recent publications have made these facts familiar, and it will only be necessary to recall them briefly, grouping them in such wise as to suggest their significance as clearly as possible.

There has been a disposition among scientists for the last half century, growing constantly stronger, and finally becoming nearly irresistible, to look upon Dalton's atoms as divisible, therefore misnamed, and not the ultimate constituents of matter. Suspicion was first cast upon their simplicity and ultimateness when the spectroscope disclosed several distinct lines in the spectrum of each element; and was reinforced when it appeared that some elements had two or even three distinct spectra. Nor was the case bettered when it was found that many of the lines in the speetra of hydrogen, ealeium, iron and other elements are missing when the light from very hot stars is broken up. For the inferenee is right at hand, as Professor Bigelow says, "that at extreme, at stellar, temperatures our elements themselves are dissociated into simpler substanees."[4]

Further evidenee against the atom resulted from Professor J. J. Thomson's studies of eathode rays, strict reasoning from his eareful experiments demonstrating them to be swarms of minute particles, or corpuscles, as he ealled them, moving with veloeities approaehing that of light, and eaeh weighing about one eight-hundredth as mueh as a hydrogen atom. These corpuseles are not merely ordinary atoms of smaller bulk, for they do not obey chemieal laws, it having been aseertained, among other things, that the absorption of them by different substanees is simply proportional to the latter's specifie gravity, and quite independent of their ehemical properties.

And recently the ease against the atom, together with Thomson's ingenious demonstration of his corpuseles, has seeured further experimental foundation, thanks ehiefly to the labors of Beequerel, the Curies, and Rutherford and Soddy, on radioaetive substanees. These wonderful experiments, at onee rapid and reliable, have shown that radioaetivity eonsists in the throwing off of two orders of substances: first, atoms; seeond, rays or eorpuseles of various kinds. But the remarkable faet in the situation is that while the atomie weight of the original substanees, radium, thorium and uranium, is two hundred or more, the weight of the atoms thrown off is nearer one or two. That is, radium breaks up into, probably, helium, thrown off, and the residuum after the emission, which has a different atomie weight from either and is otherwise shown to be a distinet element.[5] The dream of the alehemist has come true and elements are transmuted before our eyes. Seienee has aehieved an unsurpassed triumph! But, as far as helping us to fortune goes, the dream might as well have remained a dream.

As a result of these discoveries, and many others similar, in general, in signifieanee, it has eome to be admitted that Dalton's atoms are very eomplex bodies, eaeh made up of a large number of corpuseles, whieh are related to one another very mueh as are the members of a planetary system, though in size eorpuscles are unimaginably minute, and the number of them eonstituting any atom is very mueh larger than the number of members in any planetary system with which we are aequainted.

[4] Popular Science Monthly, July, 1906.

[5] In a communication to *Nature*, July 18, copied in *Science*, August 2, Sir Wm. Ramsay states that copper, in the sulphate, acted upon by the emanation from radium, was "'degraded' to the first member of its group, namely, lithium." The substance of the quotations that appear later in this paper could be found repeated many times in the writings of Thomson, Ramsay and others of the new school at home and abroad.

With atoms broken up into corpuscles, the problem of the nature of matter shifts one step farther back, and becomes the problem of the nature of these tiny bodies. Of this problem two rival solutions are now in the field, offered respectively by the conservatives and the liberals. The former, while admitting that a corpuscle is in the main an electric charge, or field of electric force, maintain that the charge has a nucleus or carrier at its core, which alone is entitled to be called matter, in distinction from the electricity of the charge. Lenard, who has given to corpuscles the significant name of dynamides, has calculated the diameter of this center of actual matter, so called, and found it to be smaller than 0.3 of 10^{-10}, *i. e.*, smaller than three hundred thousand millionths of a millimeter. This means that the actual matter, so called, of a cubic meter of so heavy an element as platinum, occupies at most one cubic millimeter of space, the rest of the cubic meter being empty of Lenard's matter, and in fact entirely empty of ponderable matter, but for the electric charges.

With so much of matter acknowledged to be electric force, which to that extent successfully performs all the functions which used to be attributed to matter, it is natural, say the liberals, to inquire whether the whole of matter can not be reduced to force, whether matter is not just force and nothing more. Many facts, they say, make this altogether the more probable, indeed the only comprehensible, hypothesis.

In the first place, as Sir Oliver Lodge, who shares with Professor J. J. Thomson—another hard-headed Englishman—the distinction of leading the liberals, points out, "an electric charge possesses the most fundamental and characteristic property of matter, *viz.*, mass or inertia."[6] If the charges occupying a given space are sufficient, and their potential is sufficiently high, their combined mass will equal, and exhaustively account for, the observed mass of the matter occupying the space. This conclusion was theoretically established long since, and has recently received experimental confirmation from laboratory studies on radio-activity.

On these points, I quote the statement of Professor Bigelow, of the University of Michigan:

> Long before experimental evidence of the existence of corpuscles had been obtained, it was demonstrated that an electrically charged body, moving with high velocity, had an apparent mass greater than its true mass, because of the electrical charge. The faster it moved the greater became its apparent mass or, what comes to the same thing, assuming the electrical charge to remain unaltered, the greater the velocity the less the mass of the body carrying the charge needed to be to have always the same apparent mass. It was calculated that when the velocity equalled that of light, it was not necessary to assume that the body carrying the charge had any mass at all! In other words, the bit of electric charge moving with the velocity of light would have weight and all the properties of mass.
>
> This might be looked upon as an interesting mathematical abstraction, but

[6] Popular Science Monthly, August, 1903.

without any practical application, if it were not for the fact that Kauffmann determined the apparent masses of corpuscles shot out from a radium preparation at different velocities, and compared them with the masses calculated on the basis that the whole of the mass was due to the electric charge. The agreement between the observed and calculated values is so close that it leads Thomson to say: "These results support the view that the *whole* mass of these electrified particles arises from their charge."

Then the corpuscles are to be looked upon as nothing but bits of electric charges. . . . It is this view which has led to the introduction of the term electron. . . . We have but to concede the logical sequence of this reasoning, all based on experimental evidence . . . and we have a universe of energy in which matter has no necessary part.[7]

Facts as many and as significant as these, added to the reasoned conclusions of philosophy and psychology, would seem adequate to settle the controversy in favor of the dynamic theory of matter, were it not that we are dealing with an idol of the tribe, far more difficult to shatter than the golden calf. But more remains to be said. The validity of a hypothesis rests not only upon the facts that support it, but also upon the ability it gives us to explain puzzles in fields adjacent to its own. This makes it worth while to mention, though space will not allow explanations in detail, that a number of knots in physical theory, that before had to be cut or else left alone, can be handily untied by the dynamic hypothesis. Professor Bigelow is again my authority in the statements, that the theory explains the highly puzzling property of valence, and that "An electronic structure of the atom furnishes a basis from which a plausible explanation of the refraction, polarization and rotation of the plane of polarized light may be logically derived."[8] These explanations bulk large in the aggregate, and the exclusive ability of the dynamic theory to make them adds significantly to its credibility.

As an alternative to the dynamic theory, thus substantially supported, the conservatives have little to offer, indeed, in the last analysis, nothing but a word. The "matter" they refuse to identify with force shrinks down to John Locke's "something, I know not what," by which a portion of the mass of bodies is to be accounted for. But, Sir Oliver Lodge remarks, "it would be equally true to say unaccounted for. The mass which is explicable electrically is to a considerable extent understood, but the mass which is merely material (whatever that may mean) is not understood at all."[9] "What is this matter which so many insist we must assume?" Bigelow asks, and answers:

No man can define it otherwise than in terms of energy. . . . Starting with any object and removing one by one its properties, indubitably forms of energy,

[7] Popular Science Monthly, July, 1906. Instead of conceiving matter as explained away, energy taking its place, I prefer to conceive of it as *explained as being* energy and nothing else. This difference in terminology is unimportant, but might lead to confusion if not pointed out.

[8] *Loc. cit.*

[9] *Loc. cit.*

we are finally left with a blank, a sort of hole in creation, . . . The last resort is the time-honored definition, "matter is the carrier of energy," but it is impossible to describe it. The assumption that matter exists is made then because there must be a carrier of energy. But why must there be a carrier of energy? This is assertion, pure and simple, with no experimental backing.[10]

When solidity, and mass or inertia are adequately explained as dynamic facts, and many puzzling physical facts are similarly accounted for, it is surely superfluous to seek further explanation in something more to be called matter, especially when no man can tell or ever has told us what he means by the word.

This is not the place to set forth what we know about electric charges, but some mention should be made of the unification introduced into our knowledge by accepting these minute bodies as the building stones of the grosser structures more immediately experienced.

A word first as to their size:

We are sure, says Lodge, that their mass is of the order one thousandth of the atomic mass of hydrogen, and we are sure that if they are purely and solely electrical their size must be one hundred thousandth of the linear dimensions of an atom: a size with which their penetrating power and other behavior is quite consistent. Assuming this estimate to be true, it is noteworthy how very small these electrical particles are, compared to the atom of matter. . . . If an electron is represented by a sphere an inch in diameter, the diameter of an atom of matter on the same scale is a mile and a half. Or if an atom of matter is represented by the size of this theater [the Sheldonean], the electron is represented on the same scale by a printer's full stop.

He proceeds a little later:

It is a fascinating guess that the electrons constitute the fundamental substratum of which all matter is composed. That a group of say 700 electrons, 350 positive and 350 negative, interleaved or interlocked in the state of violent motions so as to produce a stable configuration under the influence of their centrifugal inertia and their electric forces, constitute an atom of hydrogen. That sixteen times as many, in another stable grouping, constitute an atom of oxygen. That some 16,000 of them go to form an atom of sodium: about 100,000 an atom of barium: and 160,000 an atom of radium.

On this view all elements would be regarded as different groupings of one fundamental constituent. Of all the groupings possible, doubtless most are so unstable as never to be formed; but some are stable, and these stabler groupings constitute the chemical elements that we know. The fundamental ingredient of which, on this view, the whole of matter is made up, is nothing more or less than electricity, in the form of an equal number of positive and negative electric charges.

This, when established, will be a unification of matter such as has through all the ages been sought: it goes further than had been hoped, for the substratum is not an unknown and hypothetical protyle, but the familiar electric charge.[11]

[10] *Loc. cit.*

[11] Popular Science Monthly, August, 1903.

And having gone thus far, we can not escape going farther. For two or more atoms, properly related, form molecules; these groups of forces, aggregated in large numbers, form, on the one hand, masses of inorganic matter, and, on the other, living cells; and the last, in turn, organize themselves into living, and ultimately into conscious and rational, beings, who, in the last resort, are vastly complicated activities, aware of, and, in a measure, controlling their own intricate behavior.

To an active imagination the dynamic theory opens up fields fascinating to contemplate. Look first at the practical side. Aside from energy of gross position and molar motion, we are accustomed to think of heat and other forms of chemical energy as the only ones available for human use. But Wetham tells us that:

> As a mean value, we may say that, in mechanical units, the energy available for radiation in one ounce of radium is sufficient to raise a weight of something like ten thousand tons one mile high.

And later that:

> The energy liberated by a given amount of radioactive change . . . is at least 500,000 times and may be 10,000,000, greater than that involved in the most energetic chemical action known.

Admitting that our coal measures and iron mines may in time give out, it is evident that the present generation need not feel greatly alarmed. For who will deny to ingenious man the ability to harness these literally stupendous new forces as he has their weaker predecessors?

And on the theoretical side the gain is no less great. A respectable hypothesis, which experimental, and even laboratory methods can test, correct and enlarge, as growing experience demands, can, even in its initial form, give unity to our thinking. It not only reduces the independent chemical elements to brotherhood in the one mother substance, but it renders matter, as essentially activity, homogeneous with active mind, thus freeing us from the hopelessness of dualism, and giving a monistic view of the whole of things. And nowhere is utter death to be found. The universe, active through and through, comes out from under the heavy hand of rigid mechanism. Spontaneity is at its heart, and in the marrow of its bones. But lawless and chaotic it is not. There is regularity in the operation of its minutest parts, and organization, harmonious coworking is the law of its being, from the cooperative union of electrons into atoms to the organization of men into societies, and possibly farther still. But the order and harmony are not imposed from without by an alien power; as the laws of children's play, they are the natural rules of behavior of spontaneous beings, following, unhampered by others besides themselves, the promptings of their interacting natures.

FARM TENANCY A PROBLEM IN AMERICAN AGRICULTURE

By Professor HOMER C. PRICE
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THE per cent. of American farms operated by owners is constantly decreasing. The census for 1900 shows that over one third of the farms are operated by tenants and that in the last twenty years the per cent. has risen from 25.5 in 1880 to 35.3 in 1900.

This tendency toward tenancy has been and is viewed with alarm by the thoughtful American farmer. One of the boasts of American life has been the independence of ownership of its people. American agriculture in particular has been made up of a class owning their own farms. Land has been in greater abundance than labor or capital and has been dealt out with a lavish hand by the government. Since 1863, 233,043,939 acres of land have been given away in homesteads of 160 acres each, under the "Homestead Act" of 1862. For the man who wanted a farm there has been an opportunity to get one for taking it up and establishing a home. And the distribution of this land has not been confined to any one year, but quite uniformly distributed throughout the last forty years, and since 1900 more land has been given away by the homestead entries than ever before, as shown by the following statistics:

Public Lands of the United States taken up in Homestead Grants since 1900

Year	Acres
1900	8,478,400
1901	9,479,275
1902	14,033,246
1903	11,193,120
1904	10,171,266

With these large areas of public lands being given away each year, and with a farming population that is constantly decreasing as compared with the population engaged in other occupations, why should the farmers of our country be losing the titles to their farms? Is it a harbinger of an American peasantry, and are we drifting toward landlordism? When compared with European countries, the United States is neither first nor last in the matter of tenancy of her farm lands. In Germany 12.38 of the farm lands are cultivated by tenants, in England 86 per cent., in France 47.2 per cent. and in the United States 23.3 per cent. of the *total* farm lands.

The distribution of this tenancy in the United States varies greatly, depending upon geographical location.

TENANCY AND LAND OWNERSHIP IN THE UNITED STATES IN 1900

	Owners	Tenants
North Atlantic States	79.2	20.8
South Atlantic States	55.7	44.3
North Central States	73.1	26.9
South Central States	51.4	48.6
Western States	83.4	16.6

The southern states have by far the largest amount of tenancy, which is due, no doubt, in a large degree to the negro population. When the slaves were freed, the large plantations were broken up and instead of the system of slavery there sprang up the system of tenancy which, from the standpoint of economic production, has been worse than slavery, and the lands have been depleted of fertility and have produced a scanty living for both the tenant and the landlord, whereas under the old system they would have produced an abundance for owner and slave, and their fertility would have been maintained.

In the northern states the conditions are different—and other causes have entered into the problem of land ownership. In the North Atlantic states, characterized by their granite hills and sterile soils, the problem of tenancy has not been as great as the problem of abandoned farms. Farms were deserted because no one could be found to rent them and owners stayed on them because they could not sell them. The young men have gone west, to the more fertile lands, and allowed the farms to revert back to nature. Within the last few years, the high prices that have prevailed for farm lands in the middle west have created a demand for the abandoned farms of New England, and many of them have been taken up.

Economists claim that tenancy is a step toward ownership, and that the young man who purchases a farm is first a renter and then a farm owner. If such is the case, the state of tenancy is but temporary, and an increase of tenancy would be indications of prosperity, and would simply mark a step in the process of acquiring land ownership. But, if this is the case, the per cent. of farms held by tenants should not continue to increase indefinitely, but should soon begin to decrease—however, this is not the case, and more American farms are constantly going into the hands of tenants.

For a closer investigation of this subject let us take the state of Ohio, which is typical of the North Central states. In 1880 the per cent. of tenancy in Ohio was 19.3, in 1890, 22.9, and in 1900, 27.5. The state is naturally divided into four distinct agricultural divisions. The northeastern part of the state is made up of more or less rolling land, and a soil that is largely clay or clay loam. The soil is adapted to dairying and the growing of wheat, oats, timothy and pasture, but not to corn. The southeastern part of the state is made up of the non-

Map of Ohio showing the Per Cent. of Farms operated by Tenants as Reported in the Twelfth Census 1900.

glaciated part of the state and is preeminently hilly and sterile, and is by far the poorest agricultural section of the state and contains the lowest-priced land in the state. The southwestern part of the state embraces the Miami river valleys and is made up of the most fertile and valuable agricultural lands of the state. The northwestern section of the state is made up of the newest lands in the state, principally level lands that have necessitated draining, but after being reclaimed have proved to be exceptionally fertile lands.

On the accompanying map, showing the per cent. of tenancy in each county in the state, as reported in the twelfth census, it will be seen that the largest amount of tenancy is to be found in the southwestern section of the state, in the Miami river valleys, and the most fertile section of the state; and, if the accompanying map showing the decennial valuation of lands in the state as reported for taxation is also compared, it will also be seen that there is a close relationship between

MAP OF OHIO SHOWING THE VALUATION OF FARM LANDS PER ACRE, BY COUNTIES, AS REPORTED BY THE DECENNIAL BOARD OF APPRAISERS IN 1900.

the values of land and the per cent. of tenancy. That is, the highest per cent. of tenancy is to be found on the most fertile land. It is not because tenancy tends to increase the fertility of the land or to increase its valuation, because such is not the case, but rather the opposite. But it is due to the fact that the more fertile lands are the best investment for capital and are more eagerly held as investments than any other farm lands. In the fertile counties of the state, where the percentage of tenancy is high, farms that have been inherited by children who have gone to the city to live have been held as investments. They are readily rented, so that they will yield a fair return on the investment, and at the same time the sentiment of keeping the old homestead is observed. In this way they are rented out for cash, or a share of the crops produced, and they thus pass into tenancy. On the less fertile lands of the state, such as are found in the southeastern part, the per cent. of the farms held by tenants is low, and the value of the farm lands is low. The lands are poor investments for capital, and farms inherited by parties no longer living in the section are turned into money as quickly as possible. Loose capital will not go into such territory and buy such farms just as an investment. The same principle holds true in a comparison of the states as of the counties. In the North Central states the average tenancy of farms was in 1900, 27.9 per cent. By states it was as follows:

	Per Cent.
Illinois	39.3
Nebraska	36.9
Kansas	35.2
Iowa	34.9
Missouri	30.5
Indiana	28.6
Ohio	27.5
South Dakota	21.8
Minnesota	17.3
Michigan	15.9
Wisconsin	13.5
North Dakota	8.5

Illinois and Iowa are acknowledged the best agricultural states in the union, as well as in the North Central division, and hold first and fourth place, respectively, in this group of states—the great agricultural states of the union. Our most fertile lands are gradually drifting into the hands of tenants, and unless the movement is stayed the agriculture of these farms will decline.

Tenancy, as it now exists on American farms, is detrimental to the agricultural welfare of the country, from both an economic and a social standpoint. Farm leases, as a rule, are of short duration; this is an incentive to the farmer to only have regard for the present productiveness of the land and to disregard any methods of maintaining the fertility of the land. Short leases result in a transient population that is demoralizing to the farmer himself and to the community. The old proverb, "A rolling stone gathers no moss," is no more aptly illustrated than in the case of the tenant farmer who moves from farm to farm, never remaining more than a few years in a place. Such a tenant is not interested in improving the farm unless immediate results can be realized; he is not a permanent citizen of the neighborhood and can not be regarded as a reliable constituent of the school or church. Absent owners of such farms are not interested in the improvement of the buildings and equipment of the farms, the building of better roads, the maintaining of better schools or any public improvement that will add to the expenses of the farm unless it will give a proportionate return at an early date.

In England the detrimental effects of farm tenancy that have been mentioned are in a large degree removed by the long periods which tenants occupy the same lands; father, son and grandson occupy the same farm throughout their lifetime, and the land owners are satisfied with a low per cent. of interest on their investment and have no thought of changing their tenants. Under such conditions there is little chance for a farm tenant to become a farm owner, and, in most cases, little desire.

In the north central states of the United States it is becoming more difficult for the farm tenant to become a land owner; prices of farm real estate have advanced so that it is becoming more and more difficult for the farm hand to own a farm. On the other hand, the present farms are passing from father to son by inheritance, and why should the per cent. of farms operated by owners decrease if one son in each family remained on the homestead, or one daughter in each family married a farmer and took up the management of the homestead?

Senator Morrill in his speech before congress in behalf of the land grant colleges, in 1858, said that, "The nation which tills the soil so as to leave it worse than they found it is doomed to decay and degradation." When these words were uttered, there seemed to be an endless expanse of public lands that only awaited the pioneer's plow to yield their virgin fertility; these lands have now been practically all taken up, and it is doubly important that the fertility of our soils should be preserved. The very fact that tenancy of farm lands tends to deplete their fertility is sufficient reason for a general interest in the subject.

Much has been written and said about the movement from country to city, and many causes have been assigned for it, but it has been the natural result of the introduction of labor-saving machinery and improved means of transportation, and fewer persons are required to carry on agriculture than formerly. However, this does not account for the decline in farm owners, and the problem still remains.

Legislation can do something to make it easier to own land than at present. The removal of taxes on mortgaged farms, the establishment of a better credit system, so that money can be borrowed more readily and more cheaply for the purchase of farm lands than is the case at the present time, would greatly add to the ability of young farmers buying their own farms.

Education that will teach a more rational system of agriculture and a greater appreciation of the possibilities of the farm and farm life will do much to counteract the tendency of farm boys to leave the farm lands that they have inherited to seek employment in the city.

SOME RECENT TRANSMUTATIONS[1]

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IT would prove of little general profit to review the elaborate alchemical literature of the nineteenth century. It may be stated that in 1832 Schneider published in Halle a history of alchemy accepting the transmutation of the metals as accomplished by those aware of the necessary procedures. The study of alchemy prospered in France,[2] although it has generally been considered that the new chemistry, beginning, as it were, with Lavoisier, put down absolutely the probability of the transmutation of the metals. The affairs of the Alchemical Association of France, the successor of the Société Hermetique, founded by Albert Poisson, are controlled by the secretary-general, assisted by seven councilors, who hold an annual meeting. Numbered among the honorary members are the astronomer, Flammarion, and August Strindberg,[3] a Swedish resident in Austria.

Although Marignac[4] acknowledged that the habitual association in nature of groups of elements, as for example titanium, tantalum and columbium, offered one of the strongest proofs that can be found for the community of their origin, it is of conservative interest to observe that von Meyer, in that charming "History of Chemistry" of his,[5] says: "The final echoes of the alchemistic problem which had for so long a period of time held the cultured of every nation in a state of tension, and had even blinded eminent scientific men, only appear to die away during the last decades of the nineteenth century." This statement remains in the last edition of his book (1906), in which are recounted the discoveries of radioactive bodies and the transformations of the emanation coming from those unique substances.

We are well aware that the problem of transmutation of the elements is not solely of academic interest from the legends, courageous, tragic, fantastic, ludicrous or iniquitous, that have been handed down. Motives characterized by harsher terms than selfishness are usually attributed these days to those who apply themselves to changing the

[1] Read before the New York Section of the American Chemical Society, October 11, 1907.

[2] See Baudrimont, "Traité de Chimie," Paris, 1844.

[3] See "Introduction a une Chimie Unitaire," Paris, 1895.

[4] *Archives des Sciences Physiques et Naturelles*, **17**, 5; *Chemical News*, **56**, 39.

[5] Page 64; see also Kopp's, "Die Alchemie in alterer und neuerer Zeit."

bountiful metals into our agreed standard of exchange, for, as a rule, such are thought, with and without reason, to be in no position to give adequate return for money advanced to perfect the methods which investors are assured will produce the desired results. Especially is this true of the possessor of so valuable a secret, who may alone soon place himself beyond financial concern through the agency the knowledge, which he seeks to share with a few preferred ones.

At the corresponding meeting of this section just ten years ago, my friend, the late Dr. H. Carrington Bolton, presented a paper on this subject,[6] dealing specifically with the publications of S. H. Emmens, of New York.

It has long been known that golden-yellow specks would occasionally show themselves in silver solutions, but could not be obtained at will. Probably this phenomenon has often led to a supposition that silver might be transmuted into gold. Silver can be converted wholly into this form by the reduction of silver tartrate by ferrous tartrate. The solutions must be rather dilute and must be freshly prepared. A red powder is precipitated; this changes to black, and on the filter has a bronze color. After washing, it is removed in a pasty condition and allowed to dry spontaneously. This form of silver is very permanent when dry. It dries into lumps resembling polished gold. By brushing a thick paste of this substance over clean glass, beautiful gold-colored mirrors are obtained. The stronger acids, even when much diluted, instantly convert this allotropic form of silver into normal gray silver; this is also effected by means of pressure.[7]

Using Lea's method, just described, as a starting point, Emmens[8] thought to extend Andrew's doctrine of critical temperatures. By "the combined effect of impact and very low temperature," the former being produced by his force engine, a substance was obtained which was claimed to be common to both gold[9] and silver, hence the name argentaurum. One ounce of silver was said to produce three quarters of an ounce of gold. It was stated that the chief source of expense incurred was in the time required for bringing about the desired molecular changes. A profit of at least $3 per ounce on all silver used was assured, however.

Sir William Crookes did not succeed, to his satisfaction, in repeating the work, although Dr. Emmens stated that during that year Dr. Cabel Whitehead, assayer to the mint in Washington, accepted six ingots of the alloy, approximately a thousand dollars in value.

[6] *Chemical News*, **76**, 61.

[7] "Gold-yellow and Copper-colored Silver," M. C. Lea, *Chemical News*, 1889, **60**, 54.

[8] Papers by John MacKenzie in the *Spokane Mines and Electrician*, February 17, 1898; and Bolton, *Chemical News*, **76**, 61.

[9] Efforts on the part of the writer at the time failed to secure samples of argentaurum from Dr. Emmens.

It may not be amiss here to state that a severe criticism of Emmens's "Argentaurum Papers" appeared in SCIENCE the same year, written by Dr. R. S. Woodward. The libel suit instituted against the critic and Dr. J. McKeen Cattell, the "responsible editor," however, never came to issue.

A number of cases are on record illustrating the methods pursued in selling secret processes for the manufacture of gold. Accounts of many of these are in my possession as a result of the assiduous search on the part of my private assistant, Mr. W. A. Hamor. A recounting of them is scarcely suitable here. Suffice it to say, that a careful analysis of the motives actuating and methods pursued presents merely an inferior picture of the perfected practises we are gradually learning of as obtaining in that circle termed "high finance."

Among many communications reaching the writer, one is of more than passing interest. Mr. R. M. Hunter, of Philadelphia, has written concerning "synthetic gold" as follows:

> I have so perfected the process that in my judgment, based upon my actual experience, gold may be manufactured at enormous profit, and to this end I have designed a plant to be erected in Philadelphia and am at this moment negotiating for the $500,000 capital for its erection. I realize that the public and most scientific men are adverse to belief in the possibility of such an enterprise, but I know what I am doing and can afford to allow public sentiment to follow its own course.

Enclosed with the letter was an affirmative affidavit. On request, Mr. Hunter promptly forwarded me samples of silver in which the gold is "growing" and some "grown-up" gold, said to have been produced by his secret process. I have not made analyses of the samples, which are here exhibited.

Any discussion of the transmutation of the elements must involve a clear understanding of what we mean by the term element. By agreement, chemists regard an element as a substance which shows a characteristic spectrum and a definite combining weight. That such characterization is inadequate, that the ground upon which the characterization is founded may be shifting sand, and not the firm rock we are wont to liken it to, need not involve the present topic, as the agreed basis suffices for our purpose.[10]

Work on transmutation has by no means been limited to efforts to prepare the noble metals. Fittica's[11] investigations on the action of ammonium compounds on phosphorus in the presence of air led him to the conclusion that a true transformation of phosphorus into arsenic takes place, and that arsenic appears to be a nitro-oxygen compound of phosphorus, namely, PN_2O. The formation of arsenic from phos-

[10] These matters are thoroughly discussed in a forthcoming work by the writer from the press of John Wiley and Sons.

[11] F. Fittica, *Leopoldina*, **36**, 40; *Chemiker-Zeitung*, 1900, **24**, 483; *Chemical News*, **81**, 257.

phorus appeared to be accomplished best under proper temperature conditions, according to the following reactions:

$$2P + 5NH_4NO_3 = (PN_2O)_2O_3 + 10H_2O + 3N_2.$$

This is contrary to Flückinger's results on "black phosphorus," as the latter regarded this modification as arsenic, it is true, but considered that the phosphorus contained arsenic. Although Fittica claimed that his phosphorus was arsenic-free, Winkler[12] asserted that this could scarcely be the case, according to the work of Wittstock[13] and Hjelt.[14] The reaction should be written as follows:

$$2P + 5NH_4NO_3 = 2H_3PO_4 + 7H_2O + 10N.$$

Undaunted, Fittica[15] maintained that by varying the conditions antimony, as well, could be produced from phosphorus. As the result of the criticisms of Gyzander,[16] Noelting and Feuerstein,[17] Christomanos,[18] Gerack,[19] Arnold and Murach[20] and Councler[21] Fittica's case has been regarded as not proved.

With the discovery of the Becquerel rays, eventuating in the isolation of radium compounds by the Curies, lines of investigation were opened up leading to truly remarkable disclosures. According to the agreement, certainly radium may be regarded an element, as it has a characteristic spectrum and well-defined atomic weight as recently verified by Madame Curie.[22]

Radium compounds give off an emanation, a gaseous body, as discovered by Rutherford. Ramsay assigns it an atomic weight of 216.5, but no definite spectrum has been assigned the emanation, although it has been plotted by Ramsay and Collie. Rutherford and his associates have shown that the emanation passes through a number of changes giving Radium-A, Radium-B, etc. So far, definite atomic values and spectral data have not been obtained for these transitory disintegration products of the emanation. The lives of some of them are very short. The greatest dignity we may assign them is meta-element.

The formation of helium from the emanation was first shown by

[12] *Berichte*, **33**, 1693 (1900).
[13] *Poggendorfs Annalen*, **31**, 126.
[14] *D. P. J.*, **226**, 174.
[15] *Chemiker-Zeitung*, **24**, 561 and 991.
[16] *Chemical News*, **82**, 210.
[17] *Berichte*, **33**, 2684.
[18] *Chemiker-Zeitung*, **24**, 943.
[19] *Chemiker-Zeitung*, Repert, **24**, 274.
[20] *Chemiker-Zeitung*, **25**, 131.
[21] *Ibid.*, **25**, 977 and 1029.
[22] *Chemical News*, **96**, 127 (1907).

Ramsay and Soddy, and later confirmed by Indrikson, by Débierne, by Curie and Dewar, by Giesel and by Himstedt and Meyer. Helium, a conventional element which is devoid of any evidence of chemical affinity, is produced by or from radium, a conventional element, but the most active substance known. This occurs when the emanation is dry, and we have reason for assuming that the emanation may in reality be an active allotropic form of helium, as ozone is of oxygen.

Recently we have been thoroughly aroused again by Ramsay, who in collaboration with Cameron[23] has not only verified the above statement, but proved that when the emanation is allowed to traverse its downward career in the presence of water, neon and not helium is the gas produced. If the degradation of the emanation be in the presence of a solution of a pure copper salt, sulphate or nitrate, argon and no helium is produced. The emanation becomes one conventional element or another, dependent upon its environment. Helium, neon and argon, with the respective weights, 4, 20 and 40, are produced from the supposititious allotrope of the one with the lowest atomic weight.

We know of no case in which any one of these three obtained from other sources has been converted into the other; nor have we been informed as to whether or not the neon and argon thus produced from the emanation subsequently change into helium.

In this connection it may be stated that Meigen,[24] calling attention to the amount of energy set free in the formation of helium—about 10^9 great calories for a gram-atom of helium—states that any attempts at reversing this process are rendered hopeless. Nothing is hopeless in science. In fact, many of Ramsay's most fruitful researches have been in the investigation of the unlikely. Can it be, on the other hand, however, that the emanation is in reality a compound of these gases which are characterized by their inertness? Those who have worked with compounds of the rarer elements well know that their scission follows one direction or another, dependent upon ever so slight variations in procedure. If the emanation be, in fact, a compound, which is not likely, it is an endothermic compound involving energy with an order of magnitude far beyond anything with which we are familiar in ordinary chemical reactions. The total heat given off by one cubic centimeter of emanation is equal to about ten million gram calories, or nearly four million times as much heat as produced by the explosion of 1 c.c. of hydrogen and ½ c.c. oxygen.

Ramsay determined the presence of these gases by their spectral conduct. There can be no question of Ramsay's facts, for it is to be assumed that he took the precaution of having the minute quantities of the gases obtained and those in the comparison tubes under similar

[23] *Journal Chemical Society* (London), **91**, 1605 (1907).

[24] *Nature*, **73**, 389 (1906).

pressure, although he does not make that plain. Keeler[25] has called attention to the five spectra of oxygen which differ so widely in their appearance that there is no indication that they belong to the same substance.

Perhaps the most remarkable portion of this last work of Ramsay, the full account of which, just published, reads like a story of magic, had to do with the solutions of the copper salts in which the emanation performed its devolutions. These solutions after the removal of the copper showed the presence of lithium, the smallest metallic member of the first family in the periodic classification. So careful an experimenter as Ramsay of course took precautions to prove the absence of lithium in any of the apparatus or chemicals used by blank tests.

The facts indicate decomposition, "degradation," as Ramsay put it, and not composition, synthesis. He makes no claim to what has generally been understood by the laity as transmutation, namely, the conversion of silver into gold.

The emanation, in passing through its transformations, evolves much the greater portion of the energy produced by radium and its educts. Metaphysicians, among whom are many of the most matter-of-fact men of science, have long speculated upon the constitution of matter. Time and again it has been urged that the heavy chemical elements would eventually be broken down into lighter ones. All that was needed was sufficient energy, or the right kind of energy, properly applied. Up to the time of Ramsay's work no successfully undisputed experimental facts have been offered in substantiation of these philosophic considerations. Can it be that we have Bacon's "Philosopher's stone" in the form of a storehouse of concentrated energy, the emanation?

It is evident in this limited communication that many omissions have had to be made. I have purposely avoided the complication, which would be introduced by a discussion of the attractive electronic theory of matter. Nor has there been a desire to depict the acrobatic cerebrations of French hylozoists, although Ostwald, perhaps the greatest teacher of chemistry to-day, captains the energistic propaganda.

[25] *Scientific American Supplement,* **88**, 977 (1894).

THE RULE OF THE ROAD

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THE localization through war and barter of the cerebral centers of speech and writing (and hence of intellect) of 98 per cent. of the population in the left half-brain is the cause of right-handedness.[1] The increase of the necessary differentiation of bodily and mental function by the coordination of associated cerebral centers has resulted in a general right-handedness, right-eyedness, etc., the data by vision, audition, and for action of the right leg and foot for associated function, compelling a location of all these centers in the same left-brain and closely linked with the determining faculty of speech and writing. With the two per cent. of left-handed, the reverse of all this takes place. The mystery of the origin of right-handedness is thus cleared up. With this explanation manifest the other concurrent mystery of the rule of the road is of easy solution. Right-handedness, plus the variant circumstances of civilization, the reaction of the right-handed organism to the environment (in the language of evolution), explains all the puzzles of the rule of the road.

Primitive war, as Homer, chivalry, and present-day savage customs demonstrate, regardless of the number of combatants, was a matter of individual encounter, of hand-to-hand conflict. Even when archery, and throwing of spears, javelins, etc., came into use the essential individualism was not changed, and the shielding of the left side, and aggressive use of the right hand continued. All military tactics and drill of numbers was then established as right-handed, down to the most minute particular—and so continues, indeed, although the flung weapon weighs a thousand pounds instead of one or two pounds, and is thrown five miles instead of twenty or fifty feet. After the Trojan war, chariots fell more and more into disuse, and cavalry began to take their place, but this in no way changed the evolution of right-handed tactics. In Alexander's time the right flank of the phalanx was the post of honor, called the head, the left the tail, and marches and movements were made by the right. The commander had his station on the right. So strongly established was right-handedness as early as the half-legendary Amazonian times, that the Amazon had her right breast excised in order that she might hurl the javelin and shoot the arrow with greater freedom and accuracy.

[1] See POPULAR SCIENCE MONTHLY, August, 1904.

Thus not only right-handedness in the vast majority of people, but with it right-eyedness, etc., firmly fixed and differentiated, comes down to the beginnings of civilization. But this is far from implying that in meeting, either two or thousands of people invariably passed each other to the right. This is proved by the classical instance given by Dante in the eighteenth Canto of the Inferno in these words—translation of Longfellow:

> Even as the Romans, for the mighty host,
>   The year of Jubilee, upon the bridge,
>   Have chosen a mode to pass the people over;
> For all upon one side upon the Castle
>   Their faces have, and go unto St. Peter's;
>   On the other side they go unto the mountain.

Not only was the Papal order necessary to make the crowd keep to the right in coming and going, but a barrier was erected along the middle of the bridge so that the crowd could not interfere with one another. Further particulars are given in Longfellow's note to the passage, and by other commentators of Dante. In our own times the custom of foot-passengers is more firmly established, "As was well illustrated recently in the Paris Exhibition in the case of the two large wooden bridges erected opposite the Trocadero to convey foot-passengers over the roadway. Here, although for what reason was not apparent, the authorities commanded the people to pass over the bridges to the left, instead of, as in the case of other bridges in the same exhibition, to the right. After crossing the bridges the majority of the crowd would be seen bearing to the right, causing endless pushing in crowded days." But that many, especially women and children, are to-day reckless of the rule, is illustrated in the crowded side-walks of American cities.

Whenever, and that was generally, the custom and rule of orderly government was established by military usage, the ancient and persistent habit of passing to the right arose naturally from the necessity of keeping the enemy on the left side. This was the shielded side and gave combatants greater safety, as well as insured greater freedom and efficiency for the aggressive right arm and hand.

The crux of the difficulty in explaining divergent usage is encountered by the strange seeming anomaly of English practise. Wherever English usage obtains, the carriages and horsemen pass to the left, although foot-passengers pass to the right. That the foot-passengers keep to the right is natural, because it was derived from ages of military precedent. But another and overlooked fact doubtless contributed to prevent the English walkers from adopting the wagoner's rule of passing to the left. This was the growth of town and of city life. All urban life was conditioned by narrow streets, so narrow that our modern city alleys are in comparison wide.[2] At first, indeed, there were no sidewalks, and there was room at the sides, when a cart or carriage occupied the center, for only one person to walk between the wagon and the houses. Hence plazas, open spaces and squares, were the meeting places of the citizens. Quarrels and fighting were always taking place in the "streets," garbage and refuse (*gare à l'eau!*) were thrown from the windows into the center of the streets—which thus became open sewers, and the mud, etc., of passing vehicles had to be avoided with great dexterity by the foot-passers. And literally with great "dexterity." The left or shielded side, although shields might not be used, would naturally be that presented to the center of the street. The right side was thus chosen to keep the right hand or armed side of the body free for action, to avoid the mud, to escape the refuse flung from above, etc. And if one protected a lady, she was, as to-day, given the side next the house-walls. When wider streets and sidewalks came into existence the right-passing custom was already established; and the still-remaining narrow ones in old cities insured its maintenance.

But why did the English early adopt the habit of passing their vehicles to the left? The contradictory rules have tormented visitors, evolutionists, the correspondents of *Notes and Queries,* and many periodicals of the last one hundred years, and have been epitomized in many forms, the most common being this:

> The rule of the road is a paradox quite
>   In riding or driving along;
> If you keep to the left you are sure to be right;
>   If you keep to your right you'll be wrong.
> But in walking, a different custom applies,
>   And just the reverse is the rule;
> If you keep to the right, you'll be right, safe, and wise;
>   If you keep to the left, you're a fool.

[2] St. Evremond makes his visitor say that in the Paris of his time the streets were muddy whether it rained or not, because everybody threw rubbish of all kinds into the middle of the streets. Ladies had to be carried across the central gutter on the backs of their servants. Men wore top-boots, like those of postilions. Blocks of vehicles constantly occurred, and then there was no respect of persons; ladies whose carriages happened to be entangled in them had to listen to the most frightful oaths and language. There were often duels with whips. Victory did not remain always with the most foul-mouthed. The most dilapidated fiacre would have remained where it was until nightfall sooner than have made way for a court-carriage. Blind people and blind mendicants, criminals and pickpockets thronged everywhere. To the clashing of bells were added the shouts and cries of the perambulating dealers in vegetables, milk, fruit, rags, sand, brooms, fish, and water. The water-carriers numbered some 20,000, each of whom distributed from 30 to 40 pails a day. The tumult of cries kept up night as well as day.

The English rule of the road as to vehicles obtains on the continent only in some Swiss cantons next to Italy, and in Italy. Nowhere, apparently, do foot-passengers, in meeting, ever pass to the left. The method of passing when overtaking another wagon or carriage is also a result of that adopted in meeting. If wagons pass to the right they overtake to the left, and *vice versa*. The rule of all nations at sea, including the English, is uniform—Port your helm!—*i. e.*, pass to the right! This international rule was settled in 1862, yet Harper's "Book of Facts" says that near Great Britain alone there were in the six years ending 1895, some 13,000 collisions at sea.

The English rule of the road was of course socially recognized long in advance of any formal laws or decisions on the subject. So far as I can learn, the first Act of Parliament was enacted in 1835, and reads as follows:

> Any person driving any carriage whatsoever, or riding any horse or other animal, who meeting any other carriage or horse or other animal, shall not keep his carriage or horse or other animal on the left or near side of the road or street, or, if passing any other carriage or horse or other animal going in the same direction shall not in all cases where it is practicable go and pass to the right or off side of such other carriage or horse or other animal, shall be liable to a fine not exceeding 10 shillings.
>
> Any person riding any horse, and leading any other horse, who shall not keep such led horse on the side farthest away from any carriage or person passing him on any public road or in any street of a town shall be liable to a fine not exceeding 10 shillings. (In 14 and 15 Vict. Cap. 92, Sec. XIII.)

The led horse, and especially if the man is himself mounted, requires the man's right hand in leading on the halter of the led horse. Another evident reason why the led horse should be at the right edge of the road is to avoid dangers, both to the led horse and to the approaching person, if the led horse were to pass in the center of the road, and thus graze the passing vehicle, man, or animals.

The universal ancient custom, derived from military drill and right-handed habit, of passing to the right, was therefore unexceptionally continued by all nations except two—England and Italy—and in these two it was continued as to sea-going vessels, as to led horses, and as to foot-passengers. But by these two nations the strange exception is found that vehicles pass to the left. Why?

The suggestion has been made that in England and Italy the diligences, and post-coaches, had to be protected from highwaymen and brigands and this was done by armed postilions; these sat, of course, on the near or left-hand horses, because they were right-handed men (and thus mounted from the left side of the horse), and also because in driving the left hand held the rein while the right hand was kept free to handle the firearms. The theory is that they passed to the left in order the better to fight the highwaymen, who were thus kept on the right side. This explanation is scarcely explanatory. Were highwaymen not as common in other countries as in Italy and England? Could they not and would they not as footmen attack from the left side of the road as well as from the right? Usage so widespread must have a far more generally acting and ancient habit behind it than this of robbery. All such habits as the rule of the road must have sprung from many and more primitive and humble origins, from the necessities or customs of the common people, in fact, whence as here the few later diligences and post-coaches derived their habits. The conscious legal enactment is merely the late acceptance of centuries of unconscious custom. If suddenly springing into existence, a general change must be the response to a new circumstance of powerful and general application.

Contributing customs or necessities may have cooperated to effect the change in Italy and England from the natural passage of vehicles to the right, making them pass to the left, while foot-passengers, vessels, etc., continued to pass to the right. But it has been overlooked that before vehicles had come into use horseback-riding must have set the fashion in passing because the riding of horses, asses, mules, etc., must have long preceded the existence of the wheeled vehicle of any kind. For perhaps a thousand years (as now in a large part of the earth's surface) it must have been impossible for transportation of goods or men to be effected by wagons, and only by horses, pack-mules, etc. During this time the rule of the road must have been fixed pretty rigidly, especially as the narrow "trail" or path would not everywhere allow meeting riders to pass, but only in certain wider or more open spaces. In all civilized countries, except the two mentioned, the fact that subsequent customs demand the passage to the right shows that, during the preceding centuries, the ridden horses and pack-animals must have passed to the right. One can scarcely doubt that the ridden horses of England and Italy did the same. This seems only to deepen the mystery of their contrary practise to-day.

The mystery, I suspect, is resolved by the forgotten fact of the tremendous, fashion-setting, and centuries-long influence of chivalry with its tourneys, joustings, and knightly battles on horseback, with ax, sword, spear, tilting lance or pole. Those who have studied and realize the vast domination of chivalry can easily comprehend the rôle it played as its vogue after centuries melted into plebeian tilling the soil, commercialism, and roads covered with wagons, coaches, etc. The horseback fights and mock-battles of the troubadours, minnie signers, knights, and aristocrats of these centuries were possible only by the contestants meeting and passing to the left. It is needless to illustrate the fact from histories of chivalry, from medieval legends, tales, adventures, etc., whether of the Arthurian cycle, or Ariosto, or a hundred aftercomers. The club, spear, sword or pole must be held in the right hand and the reins in the left; the horses and riders passed necessarily to the left. There could have been no game or reality of battle if the passing were to the right. The holding the spear, lance, ax or pole was dictated by right-handedness, and to fight each other they had to pass to the left. Thus right-handedness begot left-passing, owing to the peculiar conditions of the battling or jousting.

The conclusion draws itself: this must have settled the fashion of horses (and riders) passing to the left wherever chivalry was merged into wagoning by an evolutionary process. I judge it was thus transformed in Italy and England, and that on the continent the wagon and post-chaise were not slowly derived from the fashion of chivalry. We have a capital proof of the fact, as regards England, where antiquarian research demonstrates that the postilion phase of development was not long-continued or generally practised. For the postilion period (dominative and even tyrannical in France, as her literature shows) must evolutionally be considered as the intermediate between horseback-riding, and driving from the wagon-seat or box. In England the driver, as it were, jumped directly upon the wagon-seat from the ground, or on the back of the horse without a vehicle, while on the continent, for hundreds of years, the horse of the rider hauled a vehicle behind him, and the representative of the former knight and rider became a postilion. Lack of information compels me to confess that the actual and detailed steps of the evolution in Italy are not clear to me. But in England the postilion's office was short or non-existent, and in early times the drivers of wagons, carts, etc., walked, of course, on the left or near side of the horse or team. Probably the walking was because a single horse, instead of two or four, was the rule, as the costermonger's cart and the Irish car to-day illustrate. On the continent the teams were of two, or four, or more horses, and the postilion rode one of the "near" horses; this may be seen in pictures of Paul Lacroix, "The Eighteenth Century," especially that of the "Carabas," on page 448. By the seventeenth century, as is shown on pages 6, 44, etc., the driver had mounted on the box, but the postilion was continued on the wheel-horse or, in case of three or four pairs of horses, on the near leader of the team. There can be no doubt that those who have explained the rule of the road for vehicles, as due to the position of the driver or postilion on the box or seat, took *post hoc* for *propter hoc*; the custom had already been long established before either variant arose. The extreme of the *post hoc* argument is seen in the frequently adduced statement that to have the whip-hand free, the driver sits on the right side of the seat, and *hence* passes to the left in order that he may better see that the wheels of the two vehicles do not collide. A similar illusory explanation credits the English left-passing to the fact that the early drivers *walked* on the left of the horses, and consequently they passed to the left to avoid being ground between the two sets of wheels. King Arthur and Tristram and their fellows had settled that, one judges, a thousand years previously.

Why did the American colonists from England reverse the rule of the mother country as to vehicles passing to the left? That is the remaining riddle which has perplexed every writer upon the subject. There seems to be no exception, the Virginia colonists, who were so largely horseback-riders, developed the rule of passing to the right as spontaneously as the New Englanders. In Canada there appears to have been a noteworthy indecision in earlier days; in some places, as Toronto and St. John, New Brunswick, the English custom prevailed. My reports are that to-day the American custom, if we may so name it (passing to the right) is being increasingly adopted.

The change of the colonists to the American practise has been credited to the necessity of keeping to the right in snow-drifted roadways—surely an invalid argument from evident reasons. The use of ox-teams is also said to have brought the change about. This was perhaps a minor contributory cause, but, like the preceding, will not explain the spontaneity and universality of the American habit. Another explanation that has been offered for our passing to the right is that in early days of narrow and depressed roads the driver could the better judge of the danger from the bank or "lift" of the roadway on the right. Lastly, it has been suggested that lurking savages in the woods at the sides (both sides) of the road made the change of practise. But just how either cause compelled the colonial wagoners to pass to the right, or how they bettered their condition by doing so, one vainly tries to discover.

The real explanation of the change comes to light in a more careful observation and history of the actual facts and conditions of the colonial immigrants. In the first place, they were not in the beginning even preponderatingly English. We appear prone to forget that the first Puritan settlers were mostly Dutch, to which France quickly added her complement, both of continental or right-passing people. Then it must be remembered that the long first period of settlement was not only wagonless, but even horseless, and even English folk when afoot had never ceased to be right-passers. The ox-team, the ridden horse and the led horse were the first means of transportation, and all these methods would insure the beginnings of the customs of right-passing and soon establish it as the rule. It must have been a long and fashion-fixing period before the wheeled vehicle could have come into any general use to meddle with the already established custom of right passing. Most powerful too must have been the dominating factor of the long interregnum-disuse of the English custom, whereby men's minds were freed from the influence of the special force which had made the old English custom differ from that of the continent. In the old countries war and jealousy, quarrels and crime, made men watchful of each other, kept old customs in vigor, etc., while with our colonists the common enemy banded our ancestors together in friendship and mutual trust. The habits of the continental immigrant also came into action, so that with the factors of disuse, of walkers, of horse-riders, of ox-teams, etc., all uniting, the more natural and universal law came to be customary. Two other necessities cooperated to win the easy establishment of the change: When wagons came into use they were hauled by two, by three, often by four or even by six horses or mules. The driver, of course, being a right-handed man, sat upon the near wheel-horse, and guided the leaders by the "jerk-line," held again, of course, in the left hand. The "prairie schooner" was an illustration of this universal American custom, and the six-mule team of all our armies in the war of the sixties was and remains a distinctive proof of conditions which gave it birth during the earlier history of the country. When the driver left his near wheel-horse and jerk-line, and mounted the seat in the "schooner," wagon, carriage, etc., handling the pair of reins for each pair of horses, there was the best reason in the world, wholly overlooked by writers, that he should sit on the *right* of the seat as did and does the driver in England, although he did not, as do they, pass to the left. This reason is that he might operate the brake with his right hand or right foot. In a hilly country and with ungraded roads, the braking was fully as necessary as the driving. The combined force of all these factors is fully sufficient to account for the change in our country's custom from that of England.

But the most interesting and by all odds the most financially important part of the story still remains—that concerning the railways. The history of double-tracking in the United States is not yet written. An illustration of what took place on one trunk line, the Union Pacific, is not very different from that on others. This company in constructing its line across Idaho put in sidings one and one half miles long, every three miles, and located these all upon the same side of the track, the object being to utilize these as parts of a second continuous track at a later day. The English rule was of course to pass to the left, as with carriages in the common highways and streets, a rule naturally adopted in Europe, India, etc. In our country there was said to have been sufficiently active political feeling to think that "what was English was bad," and from the first this made some of the double-track railways right-hand passers. I very much doubt this; the right passing of our common wagons even in revolutionary times had become the invariable rule, and so, despite the influence of England, her engineers, etc., the right-hand rule in our own railway orders, was in the last century usually adopted. We still have three double-track railways which, owing to English habit, having started as left-passers, still continue the practise—the Lake Shore, the Chicago and Northwestern, and the Great Northern. All others have been right-hand roads from the beginning of double tracking. It is most astonishing to find that any railway in double-tracking should have adopted left-passing, because the engineer sits (or stands) always on the right side of his engine or cab, and uses his left hand on the throttle, observing the signals at his right. In left-hand roads it is plain that he is at a disadvantage in seeing the signals because of intervening trains or cars upon the track at his right. A great element of danger is thus introduced. This may possibly help to account for the existence of two exceptions to the rule in England—one between Charing Cross and Cannon Street in London, and another, one of the first suburban lines run out of London, that formerly known as the Greenwich Railway, from London Bridge to Greenwich. Various explanations have been suggested to explain these exceptions to the rule.

The danger in left-hand roads of obscured signals by intervening trains must at least complicate and make more expensive the working, and it will never be learned how many accidents and wrecks may have been caused by the unnatural method. Even on right-hand roads the signal systems alone are now costing more than the entire construction a little while ago. Some 50 miles of modern signal systems are being put in by the New York Central Railway at a cost of $60,000 a mile, or $3,000,000 in all. There are all-controlling reasons why, once established, a modern left-hand railway can not change to a right-hand one, although the disadvantages of left-hand roads grow amazingly every year. The switches into factories, mills, yards, etc., once established must be kept up, and hundreds of millions of dollars' worth of property and vested rights are concerned. A train should enter a switch "head-on," and established switches are so designed.

Incidentally the history of signals is of interest. At first watchmen or policemen were stationed along the line as signalmen using white and red flags in the daytime, and at night lanterns of the same colors. The signalmen at first stood upon the track, then to one side. The mechanical signals are at present often overhead. When the man was displaced by a mechanical device it was at first the figure of a man, with body, head, etc., and with two arms rising and falling as did the living man's arms. Then, the signal was vertically cut in two leaving the man's half-body, half-head and one arm. That one arm is now in lineal descent represented by the dropping and rising arm of the semaphore signal. A writer in *Pall Mall,* 1902, thus describes the extension of the signal system:

> However, as traffic increased, fixed signals, first of the disc and then of the now universal semaphore pattern, were introduced, and worked by hand—that is, by means of a handle at the foot of the post. The idea of manipulating a cluster of these signals, together with track switches, was suggested by the inventive genius of a lazy Irish porter. The latter had two signals, some distance apart, to attend to; and in order to save himself the walk, he counterweighted the handle of one, and tied to it a length of clothes-line. Thus while standing at the one he was able to operate the other. An inspector chanced to see the rude though efficient mechanical device, and ordered some experiments on the same principle to be carried out in Camden goods yard—for the incident occurred on the North Western Line—with the result that the system of actuating signals from cabins or boxes by means of levers and wires was introduced. The first arrangement of concentrated levers equipped with an interlocking apparatus was invented in 1843.

The entire question of working a double-track road and its signals, and especially of a left-hand road, depends upon general right-handedness, etc., particularly upon right-eyedness, and more than all else upon the fact that the driver or locomotive engineer sits or stands upon the right-hand side of his boiler or cab. The factor that has been utterly overlooked, by writers, by railway managers, by everybody connected with or interested in the problem, is that the engineer stands or sits where he does simply and solely because he is a right-eyed man. It is all as easily demonstrated as the existence of right-eyedness by the experiment with a pencil: Hold up a card or blotting sheet so that the left eye is covered by it and the right views the scene or landscape; then suddenly move the card so that the right eye is covered by it and the left eye is the used one. At once the whole scene "jumps," intermediate objects are in an entirely different relation to those more distant, there is doubt and uncertainty of localization, there is discomfort, and a clear desire and attempt to get the right eye into use. Look at moving objects and the troubles are increased; ride in the engineer's cab and they are doubled again; when sitting on the left side and looking out of the left-side window, it is necessary to put the whole head, that is, the right-eye, out, in order to be sure about the approaching objects, signals and their relations. Sit on the right side and at once it is recognized that it is only the right eye that need be put outside the window in order to see correctly and to satisfy the mind. It is most curious and of absorbing interest to see how this fact was slowly, unconsciously, blindly recognized, but without ever being uttered or brought to consciousness in the history of locomotive-engine building and early railroading. If you ask any railway official or chief engineer of a modern railway why the engineer sits on the right-hand side of his cab, disusing his skilled and strong right hand

and using the left on the lever of the throttle valve, that lever on which all force and safety depends, and you will be answered by a blank stare of wonder at such a question, or there will be something said about the wagon-driver sitting on the right of the seat, about the use of the strong right hand ready for the application of brakes, for whistling, for the reversing lever, for bell-ringing, etc. All of which is most wide of the mark.

In the beginning of engine building, there was no "cab" and even in England to-day there is none; and also no seat for the engineer to sit upon. He simply looks out in the face of the wind and storm along the right hand side of his boiler, at the track in front of him. The very earliest machines, *The Newton,* 1680; *The Cugnot,* 1769; *The Murdoch,* 1784; *The Symington,* 1786; were directed by the engineer or driver in front of the boiler, and by both hands. But as early as 1790, with *The Read,* the engineer had learned that he must stand behind his boiler, although the older method of operating from the front of the boiler reappeared as late as 1803, *The Trevicks,* in 1821; *The Griffith,* and even in 1824, *The James,* etc. In some cases, as in *The Killingworth,* 1825, the location of the engineer is doubtful. It is interesting and instructive to watch the struggle from 1790 onward between the conflicting unconscious tendencies and demands of the right-handed and right-eyed engineers (an occasional left-eyed engineer may have obscured and lengthened the progress) and the engine-makers who were still more oblivious of right-eyedness. In *The Read,* of 1790, both hands were used on the throttle and there is no intimation as to right-eyedness or the side of the engine whence the outlook was made. In 1801 in the *First Trevicks* engine, and in 1803 the *Second Trevicks,* the throttle lever was held in the right hand, and the engineer looked along the left side of the boiler. In the 1808 *Trevicks* this was also the rule. In the 1805 *Trevicks* both hands seem to have been used, and so if, as appears from the picture, the right eye looking past the right side of the boiler was the custom. The dominant influence of the right hand is steadily shown in *The Blankincop,* 1812; *Stevens' America,* 1829; *Puffing Billy,* 1813; *Blucher,* 1814; *Locomotice,* 1825; *Seguin,* 1827; *Royal George,* 1827; *Stephenson's Twin Sisters,* 1827; *Hackworch's Globe,* 1830; *Bury,* 1830. In all these, probably or surely, the driver stood upon the left side of the boiler and watched the track in front from his side. He naturally wanted to use the right hand as the throttle-hand, and had not yet discovered the ocular problem. From 1829, with *The Rocket, The Costello,* 1831; *The Lafayette,* 1837; *The Hector,* 1839; *Hinkley's Lion; Gooch's Great Western,* and all subsequent machines, the necessity of looking with the right eye along the right hand side of the boiler at the track and signals, became dominant, and dictated the placing and direction of the throttle-valve handle. With the late construction of the "cab" of the driver, the needs of the right eye were accentuated because the engineer in looking out of the window at his right hand is compelled to put no more than his right eye out of the cab-window. If he put the left eye out of the left-side window he would have to put the entire head out in order to see with the right eye. Thus right-eyedness has unconsciously compelled the driver to disuse the right hand for the naturally expert work with the throttle-valve, in order that the greater danger may be avoided that would follow both to the engineer and to his train, from putting the whole head out of the left window of the cab.

Among the many ocular problems of railway employees those relating to deficient color-perception are of great importance, but equally great are those regarding presbyopia or the failure of visual acuteness after 40 or 45 years of age, and especially should the diagnosis of right-eyedness or left-eyedness be held of prime necessity. The left hand may be allowed, somewhat against nature, to manage the throttle-lever, but the right eye must be the absolute judge of signals, etc. Undoubtedly there are a few hundred, at least, of left-eyed engineers, signalmen, etc., on our roads, and their disability for their peculiar calling is greatly endangering lives and property. Nor should it be forgotten that there are generally proportionally more left-eyed than left-handed men. As trolley-car "gripmen" or engineers, chauffeurs of automobiles, etc., the left-eyed are at only a slight disadvantage, because nothing is in front of their eyes to impede the dominant function of the right eye. Despite this fact the automobile chauffeur sits on the right-hand seat, not only because of inherited custom, but again that his right eye may have the slight advantage of position and that his right hand may be free to use in almost every instant's emergency. In our trolley cars and electric locomotives the all-important brake is operated with the right hand.

To epitomize, the resolution of the mysteries as to the origin of right-handedness and the rule of the road may be made only by grasping the phenomena as a whole, *i. e.*, by massing the facts of the entire history from prehistoric savage battle and barter to the expert locomotive-engineer of to-day running a "limited" train at the rate of a mile or more a minute on a two-track or four-track railway. Even the cave men show that right-handedness was the rule in their time, and spear-hand, shield-hand, gesture-language, digital-counting, and the tally-stick, the world over, fixed the speech and writing and right-hand brain-centers in the left half-brain—and, of course, those of the left-hand and fingers in the right half-brain. War made up the life and set all the fashions of beginning civilization, and war together with narrow streets established the custom of right-hand passing, for walkers, riders of horses, asses, mules, etc., and for drivers of all vehicles, and for vessels. For walkers and vessels no people ever changed the custom, but especially the English, while preserving right-hand passing in foot-passengers and on the sea, anomalously developed left-hand passing for vehicles, and the same, of course, for double-track railroads. What everybody has failed to see is that right-handedness is necessarily bound up with right-footedness, and right-eyedness, because all closely united functions of the body must be correlated and their centers of motion located in contiguity and upon one side of the brain, in order to make effectual and rapid all responses of the organism to circumstance or environment. This works toward a necessary and desirable differentiation of function that makes the aims of the "ambidexterity" sillies more than resultless and foolish. Because whenever a center or congress of centers is developed in one half-brain, disuse and transfer to the other half is, according to age, either impossible, faulty, handicapping, or disease-producing. Coordinated functions of the body require coordinated and contiguous nerve-centers upon the same side of the brain, at least so far as is possible. If one or two dextral factors are in opposite cerebral hemispheres, responsive and quickly-acting coordinated functions will be slower and more inaccurate than if on a single side. The English left-hand passing of vehicles is probably due to the influence of the single-hand fights on foot, tourneyings and joustings of horse-back riders, in which meeting and passing to the left was inevitable. The custom grew and continued directly into that of the wagon-drivers. In the United States there was a reversion to the right-hand passing of vehicles, because of the abeyance of left-hand passing of vehicles, and of vehicles themselves, for so long, with growth of the natural right-hand passing by walkers, horseback-riders, ox-teams, and wagons with drivers on the near-wheel horse, such as is found in the later prairie-schooner, and six-mule army-wagon. Three double-track railways in the United States still pass their trains to the left, an absurd and bad custom, expensive and productive of wrecks. But despite this the engineer sits upon the right of his cab, because he can in this place better observe the track and signals in front and to his right, and with the dominant right eye only outside of the cab-window, whereas, if sitting on the left, he would be compelled to put the entire head out in order to see with the right eye, and, even then, because of the boiler, not so well. Only right-eyedness will explain the long, doubtful, and varying custom in engine-building as to the position of the engineer in the beginning of history of railway construction and signaling.

GOLD

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DENVER, COLO.

MUCH of the romance and glamor that in former times attached itself to the mental concept and the actuality of gold has passed away, partially because the yellow metal is becoming so common among civilized people, but mainly because in the hurry of modern life we have so many other things to think of. We take it much as a matter of course, just as we do our electric lights, telephones, wireless telegrams and other modern marvels. Yet there is a potentiality and uniqueness in gold that is possessed by no other natural or artificial product in the world, not even diamonds; namely, its apparently unchangeable value.

So far as words and terms go, an ounce of fine gold has been worth among civilized people, and at any time during the last one hundred years, just $20.67, or its equivalent in English, German or French money, and no less, though at times a little more. No other substance that the reader can mention has acquired this characteristic. Violent fluctuations have occurred in the price of every commodity or product. Wheat has ranged from $1.00 to $3.00 per quarter, wool from 4 cents to 20 cents per pound, copper from $200 to $600 per ton, etc. Even diamonds have ranged from $10 to $50 per carat.

But through all these changes gold has been steadily at one price. At least one could always get the equivalent of $20.67 per ounce for it in coin. Why? Because, by legislative action, all the great nations have agreed to accept it from any source and in unlimited quantity, at their mints, and to transform it into coins of definite weight and purity, at a mere nominal charge to cover the expenses of the operation.

This is what is meant by the free and unlimited coinage of gold. Each civilized nation works up the metal into coins in a way of its own, but all upon the same fundamental principles, and from the same starting point. The result is that the gold coins of the world have a definite and unvarying value in terms of themselves. Thus, the English sovereign always contains just so many grains of chemically pure gold, and so also does the French louis the American eagle, and the German 20-mark piece, the balance being a base metal (usually copper) that is added because gold is a soft metal and would quickly suffer loss in weight if put into circulation in a pure state.

Even the resulting alloy is not so hard as the mints would like it to be, for if you put a score of gold coins in a buckskin bag, and shake them up vigorously for a few hours, you will find that each has lost slightly in weight in the operation; and in the bag, in the shape of fine particles, will be the gold that has been rubbed from each coin by contact with its neighbor.

This is what is called "coin sweating," and if you try it to prove whether my statement is correct or not, do so by yourself and keep the matter dark, for it is against the laws of all countries, and punishable by as severe penalties as those meted out to the counterfeiter. For in appearance the coin will not be altered by a moderate amount of such treatment, and if a man should steadily employ himself in the operation, and could be continually getting a stock of fresh coins to operate on, he might be able to accumulate as much as fifty cents' worth of gold dust per day as the result of his labors.

But it will not do to confuse in one's mind the metal gold with the coin gold. For while the former under the existing laws has an absolutely unchangeable value, expressed in terms of money, the gold coins of different nations vary continually in value as expressed in terms of each other. Thus, the English sovereign fluctuates from \$4.82 to \$4.89 in American money, and the other European gold coins all vary likewise. This is due, of course, to the exigencies of international exchange, and to the fact that each coin is legal tender for the payment of a debt only in the nationality whose mint has issued it. Thus, when an English wheat or cotton merchant has bought a shipload of either of these commodities from an American producer he can not pay for it in English coin, but must buy American coin to discharge his debt. This he arranges through his bank, and if the demand for American coin for the payment of such debts by Europeans is active the price for the American dollar, as expressed in terms of foreign coin, advances little by little until it reaches a point where the English merchant (or his banker) will find it just as cheap to ship sovereigns (or even uncoined bullion) over to America, take it to the mint, have it melted and manufactured into American coins, and with these discharge the obligation. When such a condition of affairs occurs the gold-exporting point is said to have been attained in London, and the gold-importing point in New York, and because of it you can never tell whether the gold you hold in your hand, though bearing the Goddess of Liberty on its face, has come from the mines of America or from those of South Africa or China. But it makes no difference, for the inherent physical qualities of the metal are the same, no matter at what place in the earth's crust it originated.

However, we are considering gold the metal, and not gold the coin, and in again reverting to the subject it is necessary to call attention to another very marked characteristic of the metal, which it shares with but few other substances that man produces. If you are a farmer, and produce wheat, cotton, tobacco or any other of the ordinary farm products, you know very well by experience that when the harvest season comes around again the crop that you sold last year will practically have disappeared, and there will be room in the markets for the new one you have for sale. Your wheat will have been eaten up, your cotton woven into clothing and your tobacco disposed of in the form of smoke. If you are a producer of food animals, or a fisherman, the same will have happened. If you are a lumberman your boards will have been put into buildings or furniture, which in due time must be renewed. If you are a coal miner your crop is transformed by the consumer into gas and smoke about as fast as you dig it from the earth. If you are an iron, copper, lead or zinc miner your commodity begins to deteriorate in value the instant it goes into usage, and in five, ten, twenty or fifty years at the utmost the articles into which the bulk of these metals are worked up will have rusted or worn out and must be replaced.

But not so with gold. The coin you hold in your hand to-day may, for all you know, have been part of the gilding of the dome of King Solomon's temple, in Jerusalem. The case of the watch in your pocket was perhaps taken from the mines of Spain by the early Romans, a thousand years before our era. The ring you give your betrothed may be wrought from a lump of metal washed by the prehistoric miner from the stream beds of Rhodesia or India.

Who can tell? For gold can not be eaten or burned up. It can only be lost, and the whole world is interested in preventing that fate, and in taking the greatest of precautions against its diminution by wear. Hence gold is what may be called a cumulative crop. The quantity in the hands of man would continually increase, if the crop were a regular one and loss could be prevented. To a certain extent the same is true of silver, but there are no other manufactured substances, except these two metals and the gem stones, that do not steadily and even rapidly deteriorate or disappear. Even gold is somewhat subject to the law of decay, for that part of the annual crop that is used in dentistry, in photography and in gilding is rarely employed again for any other purpose, and in a generation or two has gone back to earth.

How then about the annual crop of gold? Whence does it come, what does it amount to, and how long can we go on extracting it from the bowels of the earth without disturbing the qualities that it seems to have in the commercial and industrial world? These are interesting questions that can only be answered by looking backward into the history of the metal, as well as considering its position at the present day.

It is fairly well settled that the gold of the ancients came mainly from three places, namely, Asia Minor, southern India and South Africa. In the first-mentioned locality it was principally obtained by washing the banks and bars, and even the beds of certain streams, while in the last two it seems to have come more largely from crushing the outcrops of auriferous quartz veins. What is known as the Dekkan region of the peninsula of Hindustan, and certain parts of the valleys of the Limpopo and Zambesi, in South Africa, are dotted with the remains of prehistoric excavations on such veins, some of which when cleaned out show that the workers succeeded in penetrating in places as much as two hundred feet into the earth; while in the same neighborhoods we find the relics of human structures whose age is certainly only to be reckoned in terms of thousands of years. In India, after many years of tribulation, a modern gold-mining industry has been successfully reestablished on the basis of the old one, and in South Africa the region now known as Rhodesia, where the ancients conducted very extensive operations, is slowly undergoing the processes of rehabitation.

Many of the rivers of Asia Minor were noted three to five thousand years ago for the gold washed from their beds. Crœsus, one of the kings of Lydia, who became extremely wealthy through the working with slaves of some of the stream beds of his kingdom, was one of the celebrated actual characters of that country and those times, and the river of Pactolus, whose golden sands are mentioned by several ancient historians, was one of the most noted of its metal-bearing streams.

It is probable that in the prehistoric and early historic periods of civilization gold in some quantities (not large) came also from the headwaters of the White Nile in Abyssinia, from southern Persia, from some of the East Indian isles and from China. There is no evidence that the Ural deposits in Russia were known in those remote days, but it seems very likely that a fair amount of the precious metal was obtained from the flanks of the Atlas range of mountains in northern Africa.

When I mention the ancients I mean that period of the world's history (and all the unknown eras before it) that culminated in Phœnician nationality, covering the Egyptian. Babylonian, Assyrian, Hittite and Persian empires, and the vast but quiet civilization in Hindustan, China and Japan. In the main the people of those days were Asiatics and Africans, and belonged to the Semitic and Turanian races, though the Persians and Hindoos were more or less Aryan in race and language and northern in temperament.

About 1000 B.C., when Greek nationality began to assume a commanding position, and when most of the older southern empires had passed their prime, when, in fact, the day of Europe was beginning and that of Asia and Africa was declining, there was, according to history, a very marked decrease in the supply of gold coming into the channels of civilization. The southern African and Indian fields seem to have been deserted, probably because the nation that appears to have conducted operations in these localities (the Phœnician) lost its predominance. Gold gradually became scarce, and its place in business life was largely taken by silver, which came in enormous quantities to the Grecian and Roman world of the period of 1000 B.C. to 500 B.C., first from the mines of Greece, and later from those of Italy and Spain.

The placer-mining regions of Asia Minor had either become exhausted, or, what is much more likely, the industry was ruined by the continual wars that occurred in the days when Asia and Europe were contending with each other for supremacy in that rich and rugged land.

During the early centuries of our own era, when Rome was in its prime, we hear very little of gold mining, and it is extremely likely that the greater part of the yellow metal that was accumulated by the Romans came from the spoliation of older civilizations. When Rome ceased to be a dominating factor in the history of the world, and its vast empire was split into numerous small states, mining as an industry, and particularly gold mining, suffered greatly, and the Grecian and Italian and Spanish silver mines ceased production almost entirely.

It was this fact that ultimately caused the establishment of the institution of banks in northern Italy, the then commercial center of the world, and it is a curious fact that these banks were not places where coined money was deposited or dealt in, but where credits were established and maintained. Thus the great bank of Venice, which for 600 years (800 A.D. to 1400 A.D.) was really the heart of the commercial world of the day, was little more than a great bookkeeping establishment, where the trade between Europe and Asia was kept in balance by a system of transfer of credits, these credits being based upon the actual possession by the principal traders of the time of the merchandise in which they dealt.

Gold coin in the middle ages almost disappeared from circulation, and silver coins were debased by the governments with lead and zinc and tin until they were current only at enormous discount. In the middle of this period the precious-metal mines of central Europe were discovered, but they yielded mainly silver, and not much of that, so that in the fifteenth century, just before the discovery of the New World by Columbus, commercial Europe was really in great need of coin metal.

In 1492 the western continent was discovered, and in 1498 the Portuguese navigator, Vasco da Gama, first made the passage to the East Indies by way of the Cape of Good Hope, and almost simultaneously other navigators of the same nationality landed on the eastern coast of South America and took possession of the country for the throne of Portugal, under the name of Brazil.

History tells what a marvelous change came over Europe as the spoils from the East Indies, consisting mainly of gold and precious stones, and the silver and gold from Mexico and Peru, began to flow into the channels of trade. This was intensified when the Brazilian gold fields (placers) were opened in 1675, and under the impetus of this fresh and enormous volume of new circulating medium the modern era began.

But as yet there was no such thing as an established precious-metal mining industry. The millions that had come from Spanish America and the East in the years between 1510 and 1700 were largely spoils, or the result of crude operations on alluvial deposits, and when the flood began to slacken Europe fell on hard times again, like a young rake that had lived beyond his income. This brought on the era of dissatisfaction that caused the beginning of emigration among the French, English and Dutch to North America, resulting in the partition of the continent among these races, and the formation of the American republic and the colony of Canada, where up to the middle of the nineteenth century (less than seventy years ago) gold coin was almost unknown, and the real medium of exchange was mainly the Mexican silver dollar.

In 1849 the gold fields of California and Australia were almost simultaneously discovered, and during the following ten years more of the precious metal was produced and turned into the channels of trade than had come from the earth for a thousand years previously. But as most of this was derived from alluvial diggings that were quickly exhausted it was really not until 1860 that the modern industry of gold mining began.

Placer or surface mines, where the gold exists in the form of fine grains or dust, are productive and profitable for a time, but are short-lived, while vein or reef mines that extend indefinitely into the earth are permanent, and when these began to be attacked, and machinery was devised to crush the quartz, and quicksilver employed to gather and catch the golden grains, and when finally a smelting industry came into existence, so that the so-called refractory ores could be treated and their precious contents recovered, then and not till then did gold mining become a well-defined business, and the production of the metal fairly constant and regular.

It is a marvelous tale, this history of gold, and wrapped up with it are clues to many obscure points in the story of civilization. For, as the blood to the human system, so has gold been in the commercial world, the circulating medium carrying life to all parts of the social and political organizations that men have constructed.

As already stated, gold mining is of two kinds, or rather the metal occurs in two different ways, each necessitating a particular kind of treatment to recover it. In the one case it is found in the form of a fine dust or grains, and to some extent as large nuggets, in the surface soil or débris, and it is gathered by washing such deposits in troughs called sluices with water. The gold by reason of its weight settles on the floor of the sluice, while the lighter gravel and sand are carried away. These are called placer or alluvial mines, and to this class belong the ancient fields of Asia Minor, the earlier Brazilian producing regions, the areas in California and Australia that yielded so enormously in the years between 1850 and 1860, and the Klondike and Nome deposits of Alaska of the present day.

Geologists tell us that the metal accumulated in these places during countless ages, as the result of erosion caused by rain, frost, heat, cold, glacial action, etc., operating on old granitic and schist rocks, in which occur veins, lodes, reefs and ledges (as they are variously termed) of quartz, which quartz is impregnated with particles of the yellow metal, or with crystals of ores of other metals, such as iron, copper and lead, that contain gold in a state of mechanical or chemical combination. And it is a fact that the deposits of each great alluvial field when followed up have led the explorer to areas of country (usually mountainous) where such quartz veins are found, and it is the exploration and working of these veins that constitute the other kind of gold mining, called quartz mining, which is the permanent form of the industry, and which is now in progress in America, Australia, South Africa, Mexico and India, and is coming slowly but surely into existence in Russia, Brazil, Alaska and Japan.

Alluvial or placer gold mining may be and generally is carried on with a very simple equipment. It is not a business that requires capital. With a pick, shovel, pan, some boards and nails, a hammer and saw and a few pounds of quicksilver, the energetic miner may start in business, and will rarely fail to make expenses and good wages. If he is one of the lucky ones, and gets hold of a rich piece of ground, he is rewarded with a fortune in a very short time.

On the other hand, after an alluvial field has been worked by the individual miner in his rather crude way, and is approaching exhaustion by his methods, it is common for a large number of claims to be consolidated under company or syndicate management and reworked. When this occurs systems of operation are inaugurated by which thousands of cubic yards of ground are washed daily, and modern capital may be advantageously employed in the creation and operation of the installations devised to accomplish the work. These consist of long ditches and pipe lines to bring in the water, lines of sluices in which to do the washing, dredges, elevating devices, undercurrents, etc. There have been built to date over 50,000 miles of ditches in California alone for use in this branch of business, and more than 200,000 miles in all the gold-producing states of America.

Placer gravel varies in value. The unit of quantity is a cubic yard. In the early days of a new field the ground must carry at least $1 per cubic yard to be attractive to the individual miner or small capitalist. Later, under consolidation and extensive operation, plenty of money can be made out of material carrying fifteen cents per yard, if the physical conditions surrounding the operation are good; that is, plenty of water available and a good dump. At a number of places in the west and in New Zealand good profits are being made from ground carrying much less than fifteen cents per yard.

The business of vein or reef mining is a very much more elaborate and complicated affair. The lodes or veins of gold-bearing quartz that nature has distributed in certain localities in the rocky crust of the earth are from a few hundred to a few thousand feet in length, so far as their outcrop at the surface is concerned, and from a few inches to a dozen feet or more in width. They extend downward no one knows how far, for as yet the deepest explorations made on any one of them have revealed no termination, though at several shafts in America, Australia and South Africa explorations have been pushed to depths of over 3,000 feet.

But the quartz of the vein changes continually in value. Here there may be but a trace of the precious metal, while a few feet or yards away a ton may contain as much as $50 worth. Generally, however, the gold is dispersed throughout the vein in patches called "ore shoots," so that certain areas are clearly payable and others not. This is wholly a relative term, depending upon the width of the quartz, its hardness, the nature and condition of the walls, the presence or absence of water, the price of labor, of explosives and of supplies in general, the cost of power for hoisting, pumping and milling, etc. In Mexico, America and Canada money can generally be made on a vein of a width of five feet, that will yield gold to the extent of $5 per ton, and in a number of instances, where the vein is larger, ore worth much less is yielding handsome dividends. Thus, the Homestake mine in South Dakota is paying magnificently on ore that produces on an average about $3.50 per ton, while the Treadwell mine at Juneau, Alaska, is doing finely on $1.50 rock. On the other hand, in Kalgoorlie, the great Australian gold district, where the veins are comparatively narrow but rich, and all working expenses high by reason of the desert character of the country, the costs connected with mining and milling rarely are less than $7.50 per ton, and in South Africa, where labor has been poor, company management expenses abnormally large, and the payable reef less than twenty inches thick, costs will average even a little more than in Australia.

Now that, at last, after centuries of irregular and haphazard production, the business of gold mining is on a stable and permanent foundation, it will be interesting to take account of the current annual crop of gold of the world. That the reader may acquire a mental grasp of its physical proportions it will be well to start with the fact that for the year 1906 this crop weighed nearly 674 tons. A cubic foot of pure gold will weigh just 1,204 pounds, so that the product of the world's gold mines for that year could be all packed in a room ten feet square and nine feet high. This cube was worth in money $407,-379,893, and it came from the following places:

South Africa (Transvaal, Rhodesia and West Coast) ...	$133,634,506
America (United States and Alaska)	96,101,400
Australia, Tasmania and New Zealand	82,237,228
Russia and Siberia	22,469,432
Mexico	16,639,350
British America (Canada and New Foundland)	12,116,432
British India	11,925,711
Central and South America	10,970,187
Japan and Korea	7,000,000
Europe (except Russia)	5,616,039
China	4,500,000
All other countries	4,169,608
	$407,379,893
Gain over 1905	$29,411,750

Judging by the experience of the last thirty years, during which the industry has been forming and steadily acquiring those characteristics that indicate stability, it is probable that under normal conditions, and if the laws governing the discovery and exploitation of gold mines in the various countries and those affecting the selling price of the metal (coinage laws) do not materially alter, each year will show a gain of about 5 per cent. in the amount and value of the annual crop.

At the present time, according to calculations and estimates made in 1900 by the director of the United States Mint, the gold that has been taken from the mines of the world since the discovery of America has amounted in quantity to about 21,424 tons, and in value to more than $12,600,000,000.

Now, of this vast total, the astonishing fact is that nineteen per cent., or nearly one fifth of the whole, has been taken out in the last ten years; thirty per cent., or almost one third, in the last twenty years; forty-one per cent. in the last thirty years; fifty-four per cent., or over one half in the last forty years; and sixty-eight per cent., or more than two thirds, in the last half century.

Assuming that no increase at all occurs in the annual output, this amount will be doubled in thirty years, while, if an annual increase of five per cent. is attained, the doubling will be accomplished in less than twenty.

What effect on the commerce and trade of the world will result from the creation in so short a time of so immense an amount of new and indestructible wealth, with a debt-paying quality based wholly on tacit agreement among nations, remains to be seen. That a general advance will occur in the market price of all other commodities may be confidently expected. That interest rates as a whole will decline should be quite as certain. That wages should advance seems also natural, for with that amount of new capital arising in so short a time every department of human activity is bound to be stimulated, and this will create an enormously increased demand not only for all those things that machinery and art can produce, but also for those that can only be brought into being by human hands and human service.

Of course strikes, tumults and wars may for a time cut down even the normal output, as was the case when the South African mines were closed by the Boer war, but this is very unlikely. The financial world has experienced the discomfort that occurs when its gold supply is interfered with, and is not likely to permit another such happening. In other words, the gold-mining industry, like all other international industries, makes for international peace.

An examination of the table of production for 1906 shows that nearly eighty-three per cent. of the total output was made by the Anglo-Saxon world. This is a most significant fact, and the proportion is so overwhelming as to leave no doubt whatever as to the communities that are to stand at the apex of material humanity during the twentieth century. When one looks for the causes that have led up to this astonishing predominance it is necessary candidly to admit at once that it can not be only a question of race, for the gold mines of North America, Australia and South Africa were unknown when Britain sent out her sons to these new lands. It was the lust for gold that sent the Spaniards and the Portuguese abroad, but it is the desire for homes that has spread the English people over the face of the earth. Back of this is the love of freedom, resulting from a national life that has evolved through the centuries a code of human laws fostering individuality and encouraging individual effort. So long as the great men of the race whose dwelling places encircle the globe preserve these ideals, so long will they remain secure and in the lead.

And the commanding position they hold at the present time may be credited entirely to the establishment and growth during the thousand years of English history of the principle (somewhat obscured in certain parts of the English-speaking world) that the land and all that is in it belongs to the people, and that the usage thereof is their direct and inalienable and rightful heritage.

SHALL WE IMPROVE OUR RACE?

BY GUSTAVE MICHAUD, D.Sc.
SAN JOSÉ, COSTA RICA

DURING the last hundred years man has persistently and skilfully practised artificial selection on domestic animals. He has thus sometimes increased tenfold their value to him. Setting aside for reproduction those cows only which gave the greatest amount of milk, and those bulls, the mothers of which participated in the same characteristic, milk-making animals were evolved out of the former indifferent races of cows. The lean, hardy hog of the eighteenth century has been transformed into a wonderful machine for the quick making of fat. Selection practised for speed only has created races of horses which can for a short time compete with a locomotive.

While, in most cases of selection, man had in view the modification of certain physical characteristics, it can not be said that this was always his main purpose. The intellectual selection of animals has also been practised to some extent. Breeders of hunting dogs are as much concerned about what mothers and fathers thought and did in given circumstances as about their shape and color. The results of their work have been races the hunting propensities of which are quite as strong and not altogether unlike the blind impulse which prompts a New York clerk to spend one hundred dollars on hunting implements to get a few birds worth a few cents. The main difference between the hunting dog and the hunting clerk is that the former is mostly a recent product of artificial selection, while the latter is exclusively a result of paleolithic natural selection: at a time when agriculture was unknown, those families whose heads found no pleasure in hunting were slowly but steadily and surely eliminated by hunger and consequent diseases. The others remained.

And the most notable mental transformation undergone by dogs is not the developing of their hunting inclinations nor the creating of their doorkeeping and watching propensities. The dog is to-day the only animal which unmistakably loves his master, which expresses intense joy when shown some kindness or intense grief when told a harsh word. During the the long prehistoric ages, domestic dogs were treated as they are nowadays in savage tribes. Although each family kept a number of them, very little food was ever given them. Hunger killed every year many of them. Those which survived out of every generation were mostly those which had received from their masters some food in time of famine, and they were of course the most affectionate and demonstrative.

It is a popular belief that the domestic cat differs in size only from its cousins, tigers and lions. The fact is that the physical changes brought about in that animal by selection are by far less conspicuous than the mental modification. Cats belong to the most ferocious family of the carnivorous order, and no more effective natural weapon can be found than their short jaw, with its long canines, its formidable muscles and its transversal hinge. It was with this weapon that the prehistoric machairodus killed the mammoth. It is the same weapon which to-day enables the small puma to kill in a few seconds animals of the size of an ox. The first consequence of the domestication of cats has been the elimination by angry parents, generation after generation, of those cats which were most inclined to bite children when teased by them. The result of that selection has been a race which can still use its paws, but which seems almost unable to use on man its best and only deadly weapon, although the restriction is entirely of a mental order.

It must be admitted as a sad truth that, while domestic animals are specialized and brought to a high degree of efficiency, nothing is done for the selection and improvement of man, and this in spite of the fact that modern life calls for an increased specialization in every domain. It can not be said that our statesmen are indifferent to the future of our country, but, while they may know some Latin, Greek, psychology, logic, ethics and metaphysics, they and their generation are, as a rule, woefully ignorant of modern scientific thought and truth. To bring education within the reach of all is, in their opinion, the best way to prepare the coming of a superior race of Americans. They are ignorant or forgetful of the fact that neither acquired knowledge, nor acquired qualities or habits are ever transmitted to offspring. For more than a thousand years the Chinese have been changing the shape of the feet of their girls; for many generations the Flat Head Indians have been altering the shape of the head of their children; for over three thousand years the Jews have practised circumcision; all that work has to be done over again in each generation, none of the children born to these people ever showing any proof of the transmissibility of the characteristics acquired by father or mother or by both. Selection would do for them, in a comparatively short time, what mutilation has never done, will never do. It would do for us what education can not do, yet millions are spent annually for education and not a cent for selection.

Not a cent for intelligent, well-directed selection. Some mental selection is practised by man on man, but it is blind selection. Sometimes it improves the race; sometimes it makes it worse, and nobody seems to care whether it acts one way or the other. The military selection kills or keeps away from marriage ties not only the ablebodied, but also the intelligent, men, and leaves at home for reproductive purposes the weak-minded. On the other hand, we keep the robbers in prison, but this wise measure was meant for a result which it does not produce, the terrorizing of malefactors, and produces a result for which it was not meant, a decrease in the posterity of offenders. Men of genius and their families have to-day a better chance to survive than they had in the paleolithic age, but how many eminent men spend their whole life in a desperate struggle against poverty and connected diseases, because their genius is not of the kind which brings wealth through the sale of patents!

And if through sheer chance, some great mathematician is evolved one day out of the crowd, the state—who should be ever on the watch for such events and whose main care should be to preserve and increase such sources of light, progress and national glory—does nothing to protect the man of genius against care, disease or anything likely to shorten life nor to multiply the splendid thinking machine which that man is. Ninety-nine times out of a hundred our mathematician marries a woman whose family did not count a single astronomer, physicist or other mathematical mind among its members. The result of such a union is what could be expected. Although genius does not generally die out right away in the first generation, it decreases by half, and further dilutions soon bring it down to nothingness. We know that half a dozen Goethes, Longfellows, Pasteurs, Edisons or Curies will do more to illustrate a period and raise a nation in the eyes of posterity than the most prosperous trade, the most thriving industry or than ten successful wars, yet we rely on chance and on chance alone to get those men. Breeders in their treatment of cattle are more up to date in that respect than the state in its management of men.

Such is our error and some may think that it is beyond correction. In our present state of civilization, compulsion in matter of marriage is out of the question. That is true, but compulsion need not be considered when inducement will succeed. If we bear in mind that lack of money delays or prevents many marriages and that a dowry everywhere increases a girl's chances to be married, we shall have an idea of the way in which the next generation will probably solve the problem. Most young men would consent to take a wife in England rather than in their own city if they were given a life pension for so doing; most men of genius would consent to take a wife from a number of selected young ladies rather than in the crowd if they were forever freed from pecuniary cares and moreover given the assurance that another dowry would be paid at the birth of every one of their children. Why such unions should be less happy than others is not easy to see. The best conjugal harmony is not necessarily found where one of the two is unable to understand the tastes, leading thoughts and all-absorbing ideal of the other.

The nearest approach to such state interference in intelectual selection can now be observed in the city of Washington. It is of course the unforeseen consequence of laws which were not in the least devised for selective ends; but, in spite of being clumsy, slow and but little discriminating, the process which obliges thousands of men of superior intellect, drawn from all parts of the country, to reside permanently or temporarily with their wives in a city selected for that purpose, could not fail to produce the usual results. The writer has shown elsewhere[1] that in no city or section of the country, nor even of any country, can be found such a high birth rate of genius. Birth rate of genius does not mean here the percentage of men of talent, born everywhere and now living in Washington, but the percentage of those born in Washington, who are now living in all parts of the country.

Our period sees in acquired knowledge a panacea for all evils and we have a federal Bureau of Education. A federal Bureau of Selection may be a distinctive feature of a next and more enlightened period. This institution will take up the work of which the publishers of "Biographical Dictionaries of Contemporary Men and Women of Distinction" now have the undisputed monopoly. Its officers will determine who are our bachelor celebrities and where are the daughters of those who are married. This last datum will be invaluable; if a pure-blood literary woman can not be found for a promising young novelist, a half-breed genius will always be better than a woman of the type of Dickens's wife. The bureau will supervise the education of the nation's future great men; should an Agassiz marry the daughter of a Dana, it will see that Latin and Greek be not allowed to crowd out geology from the educational curriculum of the children born of such a union; fossil studies are not the study of fossils. The organization of meetings and conferences of a literary, scientific and social character, in which men and women of talent will get acquainted with each other will be another duty of the bureau. Some will say that the state can not enter the marriage agency business without losing some of its dignity. If they were transported into the room where naked recruits, huddled together like cattle, are awaiting the medical examination which will decide of their fitness to kill other men in international duels, those same critics would not raise a protest. Such is the power of traditional ideas. There is more shame in the killing than in the marrying business, and it is more honorable for the state to raise the intellectual standard of the nation than to degrade the race, physically, mentally and morally.

[1] *The Century Magazine*, November, 1905.

A TRIP AROUND ICELAND

By L. P. GRATACAP
AMERICAN MUSEUM OF NATURAL HISTORY

IV

THE Almannaja formed the western boundary of this sunken land, and for one mile this extraordinary and unique face of rock extended in a straight line like some artificial creation of masonry. A moatlike trough at its foot held the waters of the Oxara river, which leaped in a high waterfall from its northern extremity.

In the cañon of the Almannaja, from whose eastern edge the road descends to the hotel, every imaginable phase of dislocation and rupture of the surface of igneous rock was seen, and for long distances, beyond the immediate edge of the high palisade, the ground was upheaved and depressed, alternately, by the occurrence of small deep fissures, in whose obscure and hidden recesses the snow lay. These minor rips and tears in the ground were very interesting. Slaggy-looking, ropy, circular mats of the original viscous lava were seen everywhere. The complete demonstration of the viscous pasty flowage was most significant and authentic. The falling masses, blocks and columns choked up the chasms in many places, and made bridges across the rifts. This whole plain is confusedly cracked and opened, the main lines of fission running the length of the valley. The crevices thus formed showed every imaginable state of tumbling—in walls, splits and chaotic rubbish of stones and columns, quite hopelessly attacked by plants and lichens in an effort to straighten out and soften its rugged and gaunt confusion.

Our next stop was to be Geyser, where the hot-water fountains are supposed to play with commendable constancy and where—for truth's sake—we venture to affirm, they don't.

The ride to Geyser was made in two parts. We stopped half-way at a farmhouse, where I saw something of the domestic life of these people, and where—God save the mark—I ate *skyr*. Skyr is a curdled sheep's milk, peculiarly sour and preposterously unpalatable. It is eaten with cow's milk, and is thick, pasty and—intolerable. It would require a Mark Twain to do it justice. With the skyr went a tray full of dreadful bread of two varieties, one a sour black bread, looking like leather flakes, the other whiter and only a little less propitious for the appetite. A third gastronomic enormity was an awful dark brownish-yellow granular cheese in a tin. It smelt like old hay and only Providence knows how it tasted. The saving relic of this feast was crackers and coffee. Still the hospitality was sincere and appreciated, though for the honor of its recipients it may be stated that it was paid for. The guide and myself bunked in the room where the above banquet was displayed, each on a feather bed with another one on top of that as covering.

After leaving Thingvallir we followed a rude trail over stony ground in the rifted country. The ground rose, until we dominated the broad expanse of the Thingvallir vatn, the superb and enormous expanse of water lying between hills and mountains, with some steeply slanting wedge-formed mountains shooting out of its placid waters, as if partially submerged by the eastward tipping of its basin. The view backward in the clear air, in which no trace of contamination lingered, was indeed beautiful, and the little red-roofed church as a spot of color in the scene brought with it the needed suggestion of some sort of human occupancy.

We stumbled along up natural steps of rock, near the edge of the lake, sharply rising, and later crossed the dry and contorted lineaments of the Hrafnagja (raven's wing); another rift, companion to the mighty Almannaja, less august, and more rudely formed. We were now in the "lava beds," a tangled barren region strewn with fragments of rock and thinly invaded by soil and flowers. It seemed almost as if we were on the back of the land, and looking off to its dispersed members below us. The rocks about us were vesicular, slaggy and scoriaceous. Some blistered pieces might have come from a shaft furnace. This region was most desolate, marked also by low shafts or irregular prominences of rock, while with festive hopefulness cow-berry and plantain, grass of Parnassus, ground pinks and other flowers decorated the niches or clung charmingly to the ledges and interstices of the rocks.

All the while the superb pictures north and south changed and developed. We were now approaching a most congruously strange and sterile cinder range; crater-like peaks deeply disintegrated, with long absolutely bare slopes of black and red palagonitic fragments, piled up at the limital angle of rest like the slack from a mine, or the slag from a furnace. We seemed to be in a burnt-out world, as if we might be traversing the surface of the moon. The original palisaded structure of these mountains was destroyed, until they had become heaped-up cones of rubble with very dark cavities. They were the Kalfstindar in which Thoroddsen found intrusive basalts.

We descended from the "lava beds" by a steep path to a broad grassy flat meadow that skirted the very foot of the sinister Kalfstindar. The coloring, in brown, black and purple was extremely fine, and the sharp points of some hills falling away in long slopes of débris, with, here and there, remaining bulwarks of the parallel inter-

THE KALFSTINDER RANGES.

bedded igneous rocks, and with others broken down into broad mounds of flowing stream-like pebbles were wonderfully strange.

Iron oxide was significantly present everywhere, in the water and marshes, and, later, as we crossed peninsulas of outstretched combs from the mountain sides, it glistened as an iridescent film on the mirrors of the mountain streams. Heckla now came gloriously in sight over another arm of the immense plain, beginning in the Thingvallir vatn, and was superbly gleaming in its icy mantles, while removed from it to the south were the Tindfjallajökull and the Eyjaffjalla-jökull.

The beautiful Laga vatn spread its mirrory surface below us, imbedded in prairies of meadowland, and all radiant with unchecked sunshine, while along its edges and up its arms rose columns of snow-white steam from its hot springs. Here we stopped for rest at the farmhouse mentioned above, after skirting the mountains by an excellent narrow road winding through a shrubbery of dwarf birch, and huckleberry bushes.

The farm was characteristic. It consisted of five or six structures

A Little Oasis in a Lava Field.

in contact with each other, three with wooden fronts, and one with glass windows, the rest with doors entering dim vault-like chambers between immensely thick walls of stone, interleaved with turf. Behind the central wooden house, with the windows, was a high rick-like roof composed of turf and green with grass surmounted by a small square chimney, and this roof covered a crypt-like kitchen. This extraordinary troglodytal abode was entered over a stone pavement which, rising slightly, conducted the sightless visitor to the penetralia of gloom and cooking. Inside of this semi-subterranean passage, forming its walls, was a formidable structure of stone and turf. Turf and stone houses for sheep and cows and horses were scattered about. The walls of these buildings are five or six feet thick, and, once sealed in them, it seems likely that the heat of the imprisoned animals would maintain a very comfortable temperature, even in the dreadfully severe winters.

One peculiar feature of these farm colonies is the enclosure, like a wall, which marks them. In the farm I visited, this wall at one point was twelve feet thick. Within it the farm houses, a kitchen garden,

THE KALFSTINDER MOUNTAINS.

hay ricks and outlying folds are embraced, and curiously the floor of the enclosure around the houses is raised with turf, so that the whole resembles a low diminutive fortification. It seems probable that this is done to give stability to the "living unit," and enable it to withstand the mountain streams which surge around it in the spring freshets, when the mountain snows melt and to them is added the burden of deluging rains.

When we left this ideally placed homestead, in full view of the remote jökulls, of Heckla, of the Lagarvatn and its boiling caldrons, we followed the trend of the mountains, descending also to the plain below, crossing streams and zig-zagging over misleading trails. Gradually an intervening range on the horizon shut off Heckla, all but its steely cap, and over a soggy morass—the footing in such places is perilous from buried quicksands—we passed around a low mountain and found ourselves on the inclined plain of the Geyser basin, the steaming water holes emitting white plumes of condensed vapor over its verdureless tract. Long before we reached this expectant point where the object of our long journey revealed itself, we crossed one of

ICELANDIC FARM.

the most picturesque of the Iceland rivers—the Bruaau—or, at least, seen under the splendid blaze of the noonday sun, its snowy tresses and leaping crested waves appeared so. Formerly the dismayed tourist crossed it at a ford higher up than the present position of a very reassuring bridge, and the passage could not have been always easy. The water pours into a long medial crevice—splitting the basaltic floor of the stream—from either side, and, though the fall is slight, the concussion of the opposed tides is vehement enough to drive it up into turbulent waves that rush down the polished slope, below the crevice, in tumultuous disorder. At Geyser the visitor has arrived at a silicious ridge, undermined by tortuous passages, tubes and chimneys, which issue on the surface in a great number of holes, and, as Kuehler remarks, make a sieve of the ground. Some of these holes are gasping out a little sulphuretted steam, others are sputtering hopelessly with no results, others are quite lifeless, but present warm edges and yellow-stained throats; still other large circles are full to the brim of a pale green, beautifully clear, hot water, and you look down into chambers veiled and curtained with creamy geyserite. Many of

Palagonite, between Laganvatn and Geyser.

these latter are most fascinating. The larger, deeper pools are near the "hotel," and the Geyser itself is the center of a mound of sinter, about a stone's throw away. It forms a large circular pool, whose floor shelves off to a wide descending pipe, into which one eagerly strains one's eyes for a possible glimpse at the infernal machinery which works them all. It keeps its opaline eye staring wide open, sheds a few tears from time to time, which pour in little cascades down the slant outer sides, but never, by any chance rewards the tired spectator with an explosion. Still Geyser is an exciting sort of place, and what its bigger brother fails to do a much smaller fountain meritoriously endeavors to perform. In the morning and afternoon this industrious steam-pipe gets to work, and shoots up a column some fifteen to twenty feet high, and what is missed in magnitude is made up in the number and continuity of its emissions. It makes a very commendable restitution for the patience lost on its big somnolent companion. There is a very wide and profuse deposit of geyserite at this place which may extend a mile or so outward to the south from the hills north of the "hotel." Above the geyser plain on the hillside, about one hundred

ON THE WAY TO GEYSER.

to one hundred and fifty feet, and below the trap of the Laugafjall are extinct geyser sites forming six to seven well-marked craters. The geyserite broken and disintegrated builds up these mounds, and they slope down to the upper *active* geyser tract by narrow fissures or defiles (water courses), between rounded low backs of red or white ochreous soil. The source of the heat apparently lies towards the north and probably below the trap-hills.

It seems also likely that a deposit has choked up the various channels of a few larger geysers, which have thus become dissected into a number of smaller ones which by tortuous passages now are probably connected with the original larger conduits.

Then on to Gullfoss, across a "bad" river, the Tunguflјot, and over a rolling country in which there are farmhouses, bogs and singular desert-like tracts of stony fragments and sand, which latter has been sculptured and heaped up by wind. On the way the glorious high back and silver surfaces of the Bläfellsjökull are seen shining against an icy blue sky, and behind an effective frame of serrated peaks—the Iarthettur—which blackly show up in minarets and saw-tooth outlines against its frigid sides. It made a supreme picture.

THE BRUAAU ON THE WAY TO GEYSER.

The climax was the Gullfoss. For half a century travelers who have reached this waterfall have given it their enthusiastic esteem, and as a "show card" for Iceland it's a winner. It is not so large, so immense; it does not possess mere physical dimensions, but it is a spectacle of astonishing beauty, and is so set in the loneliness of nature as to produce an astonishingly strong and thrilling impression. You come suddenly in view of it after the gallop over the sand plain, and its roar, the distant confused movement of the water and the shooting spires of spray fairly daunt you. Here the waters of the Hvitaau pour over one palisade of rock about forty feet high, and turning a right-angle tumble about one hundred feet into the whirling resounding gulf of a narrow, deep cañon that is cut southward between walls about three hundred feet high, which again farther south become almost one thousand feet in height. The upper fall is broken by intercepting partitions of rock. The falls are in process of recession, and the upper, by the more rapid removal of the possibly more easily disintegrated middle bed of rock, has slipped away from its lower companion. As the water boils and surges over the descending shelf between the upper and lower falls, it makes a very turbulent display.

The Laugafiall Mountains near Geyser.

Then it dips and drops into the hidden crevice somewhere below your feet, reappearing in the constricted throat below in awful commotion. As it drops, the dashed, splintered, pulverized masses of water send up sheets of vibrating particles from which the sun evokes a galaxy of rainbows.

The basalt rock is here seen in two series—an upper and lower—and these seem separated by slaty material. This last is, however, igneous in nature, though, peeked at from the overhanging cliff, it curiously resembles a conglomerate in spots, becoming, however, near the falls, columnar. There are curved heavy columns, and parallel and converging columns, in the rock at upper points of radiation in the lower flow. The top flow is divided from the lower by an interbedded formation, which also has a sedimentary appearance. The flows are well marked and the basaltic columns well developed.

We turned our ponies backward. It really seemed as if the great wonders of Iceland were only beginning. Heckla was abandoned for want of time, and we returned regretfully to Reykjavik.

The present-day Icelander has felt the stirring agencies which

Clay and Geyserite in Ravine, Geyser.

everywhere in national life are advancing ideals, improving methods of living and awakening commercial ambition. This is more marked now since, after long years of almost fruitless agitation, the home government—I mean the governmental functions exercised in the island itself—is placed in the hands of Icelanders, and a practical sympathy with its needs has already established useful changes. It would seem dangerous to go too far in an effort to separate the island from Denmark, as a parental supervision implying support and protection is indispensable. The maintenance of banks, a more general utilization of a medium of exchange, increased facilities of obtaining manufactured articles, internal improvements, in the extension of roads, building of bridges, telegraph connections, have all sensibly contributed to awaken the Icelander, given him new satisfactions, stirred the desire for accumulation, and introduced to his attention new projects for the development of natural advantages, as, for example, the possible use of water power for electrical and manufacturing ends.

There is a strong mentality in the Icelander that is not inappositely united with imaginative power, and combined with distinctively religious propensities; such a nature under the stimulus of education develops strong and helpful personalities and remarkable powers of acquisition. Scholarship is far from uncommon, and skill in composition is admired and displayed. A slight social segregation is perhaps becoming evident as competency, educational opportunities and self-indulgence separate an upper from the more peasant classes. Yet the traditional democratic instincts remain and will always assert themselves at any national crisis. At present, political agitation for some sort of hegemony should be discouraged, and every energy bent towards the processes of amelioration by which transit over and through the island will become facilitated, more of its interior occupied, flocks increased, manufactures laid down and comfort disseminated.

THE PROGRESS OF SCIENCE

THE CONVOCATION WEEK MEETING AT CHICAGO

The American Association for the Advancement of Science and the national societies affiliated with it meet this year at Chicago, beginning on Monday, December 30. Since the American Association changed the time of its meeting from summer to winter and entered into affiliation with the societies that had been in the habit of meeting during the Christmas holidays, there have been three large meetings of scientific men—the first at Washington five years ago, the second at Philadelphia three years ago and the third in New York City one year ago. The numbers of members of the association registered at these three meetings were, respectively, 975, 890 and 934. The registration, however, does not give nearly the total attendance, as many members of the association do not register, and all members of the affiliated societies are not members of the association. It is probable that the attendance of scientific men at each of these three meetings was over 1,500, and there is reason to hope that the approaching meeting at Chicago will be as large and as important from the scientific point of view as the meetings on the Atlantic seaboard.

The American Association is divided into eleven sections, covering the range of the natural and exact sciences. It includes sections for anthropology and psychology, for sociology and economic science, and for education, which last section holds its first meeting this year. The affiliated societies that meet in Chicago include, besides the American Society of Naturalists, the national societies devoted to physics, chemistry, geography, entomology, bacteriology, physiology, anatomy, botany, psychology and anthropology, and the western

Northeast Corner of the Campus of the University of Chicago.

THE MITCHELL TOWER OVER THE GROUP OF BUILDINGS WHICH WILL BE THE HEADQUARTERS FOR THE MEETING.

branches of the societies devoted to mathematics and to zoology.

The retiring president of the American Association is Dr. William H. Welch, of the Johns Hopkins University, who will make an address on the evening of the first day of the meeting. Dr. E. L. Nichols, professor of physics at Cornell University, is the president of the meeting and will reply to the addresses of welcome to be made by the president of the University of Chicago and others. Vice-presidential addresses are to be given in mathematics by Professor Kasner, of Columbia University; in chemistry, by Dr. Richardson, of New York City; in zoology, by Professor Conklin, of the University of Pennsylvania; in physics, by Professor Sabine, of Harvard University; in economics, by Mr. Conant, of New York City; in pathology, by Dr. Flexner, of the Rockefeller Institute for Medical Research; in economic and social science, by Mr. Warner, of Cleveland, Ohio, and in education, by Dr. Brown, U. S. Commissioner of Education. Addresses of general interest will be given before many of the affiliated societies, and there will be a large number of discussions, such as the one before the American Society of Naturalists on cooperation in biological research, in addition to a very large number of special papers to be read before the sections and societies.

The migratory meetings of the American Association enable it to bring to different centers a large proportion of the active scientific workers of the country, who should stimulate the intellectual activity of the community, while at the same time the members of the association have each year the privilege of a visit to an educational center, from which they can perhaps profit as much as from the programs of the meetings. The association has not met in Chicago for forty years. During this period science and higher education in this country have entered upon a new era, and during the latter part of it Chicago has assumed its proper place of leadership. Northwestern University opened its doors in 1855, and with its well-organized schools and four thousand students has become one of the leading universities of the country. The Field Museum of Natural History, organized at the close of the exposition of 1893 and recently endowed by Mr. Marshall Field with a bequest of $8,000,000, is one of the great museums of the country and of the world. Of special interest to the visiting members will be the University of Chicago, where most of the meetings will be held. Thanks to the vast gifts of Mr. John D. Rockefeller and the liberal cooperation of the citizens of Chicago, seconded by the organizing ability of the late President Harper,

The Walker Museum of Geology.

THE RYERSON PHYSICAL LABORATORY.

the University of Chicago has enjoyed during the fifteen years since its foundation a development unparalleled in the history of education. Its grounds and buildings, its museums and laboratories, its educational methods and above all the great group of scholars and investigators who make the university will attract to the approaching meeting men of science from the whole country.

A STATUE OF JOSEPH LEIDY

OUR cities are more likely to erect monuments in honor of soldiers and statesmen than to commemorate in this way their intellectual leaders. Philadelphia should therefore be congratulated on having placed by its city hall a statue of its great naturalist, Joseph Leidy. Thanks most of all to him, but also to a group of fellow students, Philadelphia maintained for a time during the second half of the last century a certain preeminence in natural history. We may hope that the dedication of this statue of Professor Leidy on October 30 indicates that the city appreciates the golden age in its history, and will seek to regain its leading position as a center for research in biological science.

Joseph Leidy was born in Philadelphia in 1823; he spent his life in that city, and died there in 1891. He graduated from the medical school of the University of Pennsylvania in 1844, and maintaining his connection with the university as assistant and demonstrator was elected professor of anatomy in 1853. His connection with the Academy of Natural Sciences was equally long and intimate, and he was also professor at Swarthmore College. His scientific work was closely connected with Philadelphia. Most of his six hundred papers were published in the proceedings of the academy and of the Philosophical Society. His paleontological papers were based mainly on the collections of the academy, and his work on recent invertebrates on material collected in and about the city.

Leidy published over two hundred papers on the extinct vertebrates of North America, leading in the work in which he was subsequently joined by Cope and Marsh of describing the remarkable fossils of the western plains. As early as 1847 he showed that this continent was the ancestral home of the horse, whose phylogeny is one of the most interesting chapters in the history of evolution, and this paper was followed by others describing the lions, camels, rhinoceros and other mammals and reptiles, which have now no immediate representatives on the continent. Perhaps equally important was Leidy's work on parasites, on

STATUE OF JOSEPH LEIDY.

fresh-water rhizopods and on other lower forms. In 1847 he discovered the trichina in the hog, and his "Flora and Fauna within Living Animals" is a classic on this subject. His work covered an immense range. He was well informed in botany and in mineralogy, and was master of the whole field of zoology, anatomy and paleontology, both on the side of the laboratory and of nature. The complications of modern science make it unlikely that there will be another man of his type. Men must now be more specialized and smaller, and this seems to hold to a certain extent for character as well as for scientific work. Leidy was not only a great naturalist, but also a great man—simple, kind, generous and just.

SCIENTIFIC ITEMS

We regret to record the death of Professor Asaph Hall, the eminent American astronomer.

Nobel prizes have been awarded as follows: In physics to Professor A. A. Michelson, of the University of Chicago; in chemistry to Professor Eduard Buchner, of the Berlin Agricultural School; in medicine to M. Laveran, of Paris; in literature to Mr. Rudyard Kipling, and for the promotion of peace to M. Renault and M. Moneta.—The Copley medal of the Royal Society has been awarded to Professor A. A. Michelson, of the University of Chicago, and the Davy medal to Professor Edward Morley, emeritus professor of chemistry of Western Reserve University.—Professor Simon Newcomb has been elected a foreign member of the Göttingen Academy of Sciences, Mr. Alexander Agassiz of the Vienna Academy of Sciences, and Dr. G. W. Hill and Professor H. F. Osborn, foreign members of the Edinburgh Royal Society.

An oil portrait of Professor James Mills Peirce Perkins, professor of mathematics at Harvard University until his death in 1905, has been presented to the university by his sister. —A portrait of Professor Arthur Schuster has been presented to Manchester University. It will be remembered that Professor Schuster recently retired from the active duties of the chair of physics.

Mr. Andrew Carnegie has added two million dollars to the endowment of the Carnegie Institution of Washington. Mr. A. J. Montague, of Virginia, and Mr. W. B. Parsons, of New York, have been elected trustees of the institution.

THE
POPULAR SCIENCE
MONTHLY

FEBRUARY, 1908

A VISIT TO THE HANGCHOW BORE

By Dr. CHARLES KEYSER EDMUNDS
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I

Introductory

THE most striking thing, from a geographical point of view, which is to be seen along the China coast is the recurrent phenomenon which we are about to describe. The rugged coast line, the many bays, the chain of islands fringing the coast, the whole gamut of geological and geographical forms which one encounters in an intimate coastwise journey, are all very striking and grand, and yet they are static—passive, after all. Notable as they are, they are but silent witnesses of those restless and resistless forces which have brought them into being. But when one beholds the mighty Yangtse and attempts to form an estimate of the volume of silt carried seaward in the rush of its muddy waters, and tries to judge of its land-forming as well as its land-denuding powers, one stands in the presence of dynamic grandeur, which to our mind exceeds the passive greatness as of the "everlasting" yet silent hills. It is this appreciation of dynamic greatness which overwhelms an observer of the tidal bore as it sweeps in from Hangchow Bay and rushes past Haining, a solid wall of water from two and a half to three miles wide, perhaps ten, twelve or even twenty feet high, with a speed of ten to twenty miles an hour, according to the intensity of the tide. Imagine, if you can, one and three quarter millions of tons of water passing by you each minute, the rush to continue several tens of minutes, and you will have no difficulty in believing that this inrush of water makes itself felt still as a big wave at Hangchow, thirty miles farther inland, and even for some miles beyond.

MAP
OF
HANG-CHAU BAY
AND
ESTUARY
OF THE
TSIEN TANG KIANG

Unlike the bores seen elsewhere, which generally occur intermittently, the Hangchow bore ascends the river at every tide, though its magnitude and speed vary considerably with the general state of the tides, and semi-monthly maxima are attained at the third tide after each new and each full moon. The latter affords a better opportunity to witness the bore under the more impressive and majestic stillness of midnight and the light and shadow of a moonlit scene. These semi-monthly maxima themselves attain greatest intensity at the times of greatest tides. Of these the autumnal equinox is preferable because of the cool and most probably fair weather and the absence of mosquitoes. The eighteenth of the Chinese eighth month is gen-

THE BUND AT SHANGHAI. CLOCK TOWER OF CUSTOMS HOUSE SHOWS IN THE DISTANCE.

erally reckoned as the time of the greatest bore of the year. In the fall of 1906 the writer spent the first and second days after the seventh full moon (September 6 and 7) in close observation of one midnight and two noon bores.

Although observers sometimes go to Kanpu beyond the mouth of the Ch'ien-tang Kiang, and others content themselves with a view from Hangchow, from the first of these places the bore is seen when not fully formed, its two initial sections not yet united, while at Hangchow the effect, though still fairly remarkable, has completely lost its grandeur; and the best and most easily reached vantage ground is at the Haining Pagoda, though it is likely that at a point some five miles below the pagoda the bore is of even greater grandeur. This is close to where the two branches of the furious "Serpent's Head," as the

FOOT-BOAT, A FAST PASSENGER CRAFT ON CANALS IN YANGTSE DELTA. THE SIDE OAR IS BEING OPERATED BY THE FEET.

Chinese call it, meet, and some observers have reported thirty feet for its height there as against nine feet reported at the pagoda for the same bore, though we suspect that they refer to the height of the temporary waves caused by the impact of the two branches, and not to the height of the bore-front proper.

THE JOURNEY TO HAINING

Haining lies within and near the northwestern side of the equilateral triangle formed by Hangchow, Ningpo and Shanghai, and is readily reached from the last named by means of a so-called canal "train," a steam-launch towing three to six boats of various kinds. One may hire a horse-boat, Chinese or foreign style, or, as we did, take a cabin on one of the native passenger barges operated by the launch companies. Small cabins for two cost five dollars, Mexican, from Shanghai to Hangchow, and a very large one, enough for a party of six or eight, may be rented for twelve dollars, Mexican, for the one way. House-boats cost upwards of five dollars, Mexican, a day, according to size and fittings, and towing is extra.

Two or three of these launch-trains leave Shanghai from their landings in Soochow Creek every afternoon about five o'clock and with fair weather and favorable tides reach Hangchow the next afternoon anywhere after three o'clock. Three companies are now running these trains, two Chinese and one Japanese. Everything is managed in a creditable and business-like fashion, and one can make a fairly comfortable trip at reasonable expense. It is possible, using this launch service, to leave Shanghai on Friday night, see the Saturday night and Sunday afternoon bores, and be back in Shanghai on Monday morning. By private launch even better time can be made and a record round-trip of sixty hours, allowing fifteen hours at Haining to witness both a day and a night bore, and five hours of shooting during the return, was made by some Shanghai enthusiasts in October, 1902. On the other hand, the pleasures of house-boating in the region traversed, especially during the fall months, should not be underestimated, and if one is not pressed for time a very comfortable and interesting trip on a private boat, propelled by *yulow* and pole and landing you at the Haining Pagoda at the end of the third day from Shanghai, will allow a full enjoyment of the various scenes which enliven the river and canal banks throughout the Yangtse's delta. A satisfactory compromise between these two plans may be effected by taking a cabin passage on a launch train as far as Samen on the Grand Canal, which is reached at noon of the day after leaving Shanghai, and then hiring a native boat to be *yulowed* along narrow, well-shaded canals to Haining, which under fair conditions should be reached by six or seven o'clock that evening.

Leaving the wharf in Soochow Creek, Shanghai, shortly before

AN ORDINARY PASSENGER CRAFT USED BY THE AUTHOR FOR THE TRIP.
SAMEN — HAINUNG — HANGCHOW.

Long Granite Slabs forming a Simple Bridge.

sunset, we passed under the Garden Bridge, from which many pairs of curious eyes watched our departure, the sturdy little tug puffing continuously and tooting spasmodically as it entered the Whangpu River to pass along the length of the Bund and native city wharves, thus affording an unexcelled view of Shanghai's glory. After rounding a bend toward the southeast our course was southward up the river to Sankong, from there west as far as the walled city of Sungkiang, and further, winding around in a west by south direction, we passed out of Kiangsu province into Chehkiang and came to Kashing, a walled city with a customs station under the management of the Hangchow customs. Here we entered the Grand Canal and followed its southwesterly course through several unimportant but crowded places, at one of which Samen, or Shih Men, we left the launch-train and proceeded in a native boat southeasterly toward Haining by means of the by-way canals which traverse the delta as frequently as cross-roads are found in the country districts of western lands. At Samen, the Grand Canal proper makes a right-angled turn to the west as far as Dongsi, or Tang Hsi, where another right-angled turn gives it a straight course southward to Hangchow, its terminus.

All along we found the canals full of life, large boats laden with firewood passing down to Shanghai, while smaller boats with market supplies and other articles were met plying between intermediate points. Large rafts of fir or bamboo, sometimes stretching as far as one could see, excited wonder as to how four or at most five men

At a Bend in the Grand Canal.

succeeded in managing them so well. Curious foot-boats here take the place of the slipper boat so common in the Canton Delta as a rapid passenger craft. They are long narrow affairs and owe their name to the peculiar fashion in which they are propelled. A single boatman sits in the stern and *yulows*, or wiggle-waggles a large tail oar, and at the same time operates a long oar slung over the starboard side, by means of both feet placed on the inner end—one on the round handle of the oar, and the other on the flat side of a good-sized wooden block attached to the oar-end at right-angles. These boats carry passengers, mails and parcels between the intermediate places not served by the launch-trains or on the side canals.

On both sides of the canal, especially near Kashing, fine granite memorial arches and several pagodas stand conspicuous, having escaped or baffled the destroying hand of the Taipings, though most other things in this region suffered woefully. At one turning point we noticed three graceful pagodas standing side by side.

But the most frequent and most notable feature encountered during a trip on these canals is the really wonderful series of bridges under which the traveler passes. Wooden bridges, granite bridges, crude bridges, artistic and picturesque bridges, dilapidated bridges and bridges in good repair. Bridges with sloping approaches and high curving arches, bridges with one arch or with several, all devoid of prominent keystones. Bridges crowned with shops or pavilions. Bridges whose sides are covered with verdant vines and with small trees clumped at either end. Bridges from the tops of which expectant fishermen let down the great umbrella net and blame the passing boat for the non-appearance of a decent "catch." Bridges which sometimes by their massive piers and narrow arches so reduce the waterway and increase the stream's flow that the spice of danger is added for the voyager whose craft may be a little over normal size. Later, while returning from a side trip to Mokanshan on a dark and rainy night, the cabin loft for servants at the rear of the house-boat we were using was almost completely demolished by crashing into the corner of one of the side arches of the bridge at Dongsi.

On some of the straight stretches of the canal as many as three bridges were sometimes seen from a single position, for every village must have its bridge, and settlements are so frequent that a canal is a veritable "stringtown on the pike." When the canals pass through towns and villages, the natives seem to exercise their best ingenuity in obstructing the already narrow space to the utmost passable limits, by building overhanging porticos and pavilions or by mooring their craft on either side without regard to the resulting constriction. In many cases these bridge arches have more than a half-circle of opening and are fine examples of the stonemason's art and skill. With regular and

A Pair of Crude but Useful Structures

solid granite approaches on either side, having sometimes a simple open rest house, washed red on the outside, or a small group of houses at one end, about which cluster a few large trees, they often present charming pictures, especially when a bright day allows every outline to be reflected from the water and the observer is sufficiently distant to miss the inevitable dirt of a Chinese rural dwelling place.

So-called river "gunboats," usually tied up in a shady spot near a village and large mandarin family boats were frequently met with. The most curious of all the craft encountered, however, were the cormorant fishermen's boats or rafts, with the berumpled and rather miserable-looking black birds crouching upon them or swimming alongside. Usually the fisherman was stamping rhythmically upon a loose board in the stern and *yulowing* his boat at a fair pace, some of the birds swimming alongside with a bobbing kind of motion in unison with this stamping, and every now and then making a dive for fish which were no doubt expected to be attracted by the boatman's noise, though to judge from our observation the returns for all this scheming were very meager.

Occasionally a grating sound under the bottom of the boat told us that we were passing over the loose central portion of the reed and bamboo fish-traps or wires which frequently extended completely across the stream, but always with an apparently unoccupied reception or storage compartment at one corner. At other times the progress of our light craft was somewhat impeded by the heavy growths of water weeds and cresses.

The banks of the canal are everywhere green and restful, and in the case of the smaller by-ways are often completely overhung. We have seen nothing finer of the same sort anywhere, the famous Fenways of Boston not excepted. Bushes, great grasses, trees straight and tall, dwarfish and crooked trees, laurel, graceful weeping willow, flowering shrubs, and non-flowering covered with some blooming vine—the whole a beautiful fenway for mile after mile.

The predominant feature is the mulberry-tree, showing everywhere the importance of this region as a silk producer. In well-kept rows, their crooked and wide-spreading branches hid beneath rounded canopies of huge pale-green leaves, the ground everywhere clear of other growth, these little trees represent no small part of the material wealth of a region famous for the splendid silken garments produced in its chief cities.

These mulberry groves sometimes alternate with clumps of graceful bamboos or spicy odorous pines, which mark the burial ground of the near-by village. Or again there is only a fringe of mulberry trees along the bank, much as the lichee trees occur in the delta near Canton, with the paddy fields soon to become bean fields after the rice harvest, or the lotus ponds all white and pink in their September glory, lying behind this fringe or veil.

Haining was reached at eight P.M. in the midst of a pouring rain. Passing around the wall on two sides, our journey came to an end in the *cul de sac* with which the canal abruptly terminates, near a somewhat picturesque gateway in the city wall. A five minutes' walk from our mooring at the canal's end brought us to the sea wall and

A Pair of Ornamental as well as Useful Structures.

the pagoda, and after witnessing the bore which swept past us at about 1:15 A.M. we again crawled into our not overlarge boat and enjoyed a half-night's dozing on hard boards.

Some Considerations concerning Tides in General

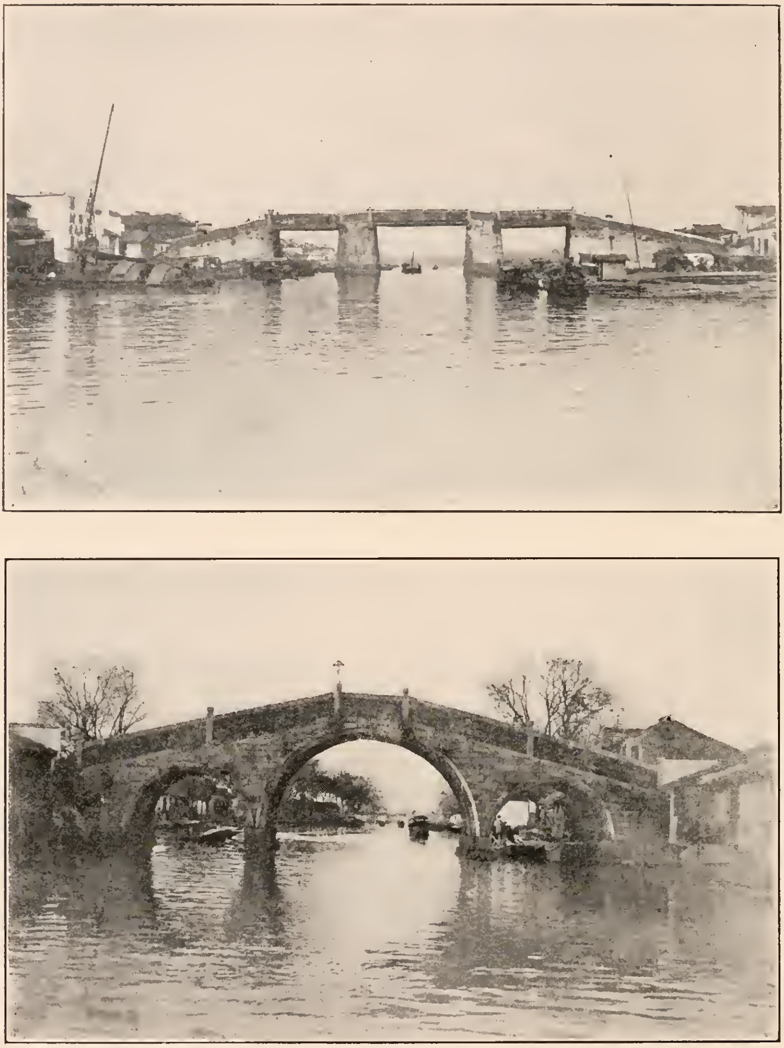
Bores Elsewhere

Before describing the Hangchow Bore as we saw it at Haining, some preliminary remarks about tides in general, and especially about tidal currents in rivers, will enable the general reader to understand better the phenomenon we are about to consider, and to appreciate its proper place as compared with other more general and ordinary tidal phenomena. This must be our justification for presenting here much that can be found elsewhere and is already matter of common knowledge, but which needs to be correlated and reviewed in this present connection.

The discrepancies in the range of the tides at different places are due chiefly to the local conformations of coasts and sea-beds. Indeed, it seems, as Sir Robert Ball has pointed out, that if the whole earth were covered with a uniform and deep ocean of water, the tides would be excessively feeble, since barometric records give no very distinct evidence of tides in the atmosphere, which is a deep and vast ocean of air embracing the whole earth to a practically uniform depth.

Along the borders of land areas the range of the tide is found to vary from zero up to seventy feet. Few of us realize how small the range is in some places, where at first sight we should expect it to be considerable. In midocean, for instance, an island like St. Helena is washed by a tide only about three feet in range; an enclosed sea like the Caspian or the Black is subject to no appreciable tides whatever, and even the Mediterranean, notwithstanding its connection with the great Atlantic, is subject in general to inconsiderable tides, the range of water-level varying from eight inches at Brindisi to two feet four inches at Trieste. The Mediterranean tides are, however, more strongly developed in the Bay of Gibraltar (where the range is from five feet to six feet five inches), the upper Adriatic and the Gulf of Gabes.

In the deep wide reaches of the ocean, the tidal elevation progresses at the tremendous rate of about five hundred geographical miles an hour. But as this is merely the passing of an oscillation whereby the particles of water are gently moved through a cycle of positions, there can be no appreciable effect upon the distant ocean bottom, on an average of two or three thousand fathoms below. When, however, the tidal wave enters a shallow sea, the friction of the bottom becomes more and more effective in decreasing the speed while it increases the height and effective force of the wave. Again, when the tidal swelling is increased in height by the convergence of the shores between which it moves, it is no longer a mere oscillation or pulsation of the great ocean, but the water acquires a true motion of translation, and rushes past headlands and through narrow channels with tremendous force and speed—a phenomenon well known along the west coasts of Scotland and Scandinavia. In some cases the advancing tide on entering a narrow inlet or estuary gathers itself into one or more large waves, and rushes up between the converging shores. Thus, owing to the gradual



A Contrast in Construction.

decrease in width and depth of the Bristol Channel the tide enters the Severn with great force, forming a tidal wave or bore which at times attains a height of nine feet and has on several occasions caused great destruction, as in 1606, 1687, 1703 and 1883. The Bristol Channel also concentrates the great wave which gives Chepstow and Cardiff a tidal range which sometimes reaches fifty feet. In like manner, the tides which enter the Bay of Fundy between Novia Scotia and New Brunswick are more and more cooped up and rise higher as they ascend the strait, till they reach a height of seventy feet. But these changes are gradual, not really sudden enough to constitute a properly

A Crude Bridge.

called "bore." Professor G. H. Darwin noted on the banks of the Severn during the spring tide in September, 1897, that there was no proper bore, but only a succession of waves up-stream, and a rapid rise of water-level.

In the case of the River Seine, which has been dyked as far as Rouen to admit vessels of twenty feet draught, it is said that there is a bore (*barre* or *mascaret*) at every tide, ranging usually from eight to ten feet. This is probably accounted for by the fact that after Candebec and Quillebœuf, the estuary is set with extensive sand-banks between which flows a narrow navigable channel.

These bores are relatively small compared with that in the Ch'ien-tang Kiang, while the destructive bore of the great Amazon is robbed of its impressiveness because it can not be well observed on account of its very magnitude; moreover, with it as well as with the other rivers it is only at spring tides and with certain winds that the phenomenon is at all striking. On the other hand, the Hangchow Bore occurs at every tide to a remarkable extent in any season and at certain times assumes colossal proportions and is always easily observable. For comparison it may be interesting to note the following description of the Amazon's bore, or *pororoca,* by La Condamine:

During three days before the new and full moons, the period of the highest tides, the sea, instead of occupying six hours to reach its flood, swells to its highest limit in one or two minutes. The noise of this terrible flood is heard five or six miles off, and increases as it approaches. Presently you see a liquid promontory twelve or fifteen feet high, followed by another, and another, and

An Artistic Bridge—a Common Type.

TYPICAL BRIDGE OF SUBSTANTIAL CHARACTER. NOTE THE ABSENCE OF PROMINENT KEYSTONES.

sometimes by a fourth. These watery mountains spread across the whole channel, and advance with a prodigious rapidity, rending and crushing everything in their way. Immense trees are sometimes uprooted by it and sometimes whole tracts of land are swept away.

Tidal Currents in Rivers[1]

There is no appreciable tidal effect in rivers due directly to the tidal attraction of the sun and moon, but the tidal wave in a river is

[1] See G. H. Darwin, "The Tides," etc., Scribners, 1898. This contains also an account of the Hangchow Bore based on Captain Moore's survey, to which we shall refer later on.

caused by the oscillation of the larger body of water into which the river empties. The sea resembles a large pond in which the water rises and falls with the oceanic tide, and a river is a canal leading into it. The rhythmical rise and fall of the sea generates waves which would travel up the river, whatever were the cause of the oscillation of the sea and quite independent of any direct action of the sun and moon on the water of the river itself.

There are four characteristics of tidal currents in rivers which are of cardinal importance in the present connection. Briefly treated, they are:

1. *Dependence of Speed on the Depth Alone.*—It may readily be shown mathematically that long waves travel in shallow water at a speed which depends only on the depth of the water, and that waves are to be considered long when their length is at least twice the depth of the water. Now the tidal wave in a river is many hundreds of times as long as the depth, and consequently it travels at a speed dependent only on the depth of the river. Moreover, its speed is very slow compared with the motion of the great tide wave in the open sea.

2. *Difference between Ebb and Flow in a River and along an Open Coast.*—On the open seacoast ebb and flow are simultaneous with fall and rise, but in a river the case is quite different. On an open coast slack water occurs at high and low water, but in a uniform canal connecting with the sea, slack water, *i. e.*, the time of no tidal current, is at mean water-level, the current being most rapid up-stream at the water-level, it ceases flowing before mean water-level is reached; and

A CONSTRICTED ARCHING. NOTE THE LACK OF PROMINENT KEYSTONE.

GUARDING THE GRAND CANAL

moment of high water and most rapid down-stream at low water. Hence the tidal current "flows" for a long time after high water has passed and when the water-level is falling, and "ebbs" for a long time after low water and when the water-level is rising. But rivers gradually broaden and become deeper as they approach the coast, and tidal currents in actual estuaries are, therefore, intermediate between those of an open seacoast and those in a uniform canal.

A STRING-TOWN ON A CHINESE "PIKE."

3. *Effect of Proper Current of the River Itself.*—A river has also to deliver a large amount of water into the sea during a single oscillation of the tide, and its own proper current is superposed on the tidal currents. Hence in actual rivers, while the resultant current continues to flow up-stream after high water is reached, with falling water-level, it ceases flowing before mean water-level is reached; and while the resultant current ebbs down-stream after low water, it generally continues to ebb with the rising tide for some time after mean water is reached, the downward stream, in fact, lasting longer than the upward one. The moments at which currents change will differ in each river according to the depth, the time and the extent of the rise and fall at the mouth and the volume of water delivered by the river; but in every case the tide rises more quickly than it falls, so that the time-interval from low water to high water is shorter than from high to low.

4. *Natural Change in Shape of a Wave Advancing into Shallow Water.*—The demonstration is too technical to be included here, but it can be proved analytically that a wave progressing up a river must change its shape so that the front slope gets increasingly steeper, and the rear slope more gradual. If this steepening of the front slope be carried to an extreme, the wave would present the form of a wall of water, but the mere advance into shallow water would not by itself suffice to produce so great a change of form without the aid of the natural current of the river, which cooperates with this change in the shape of a wave as it runs into shallow water, so as to exaggerate the steepness of the front slope. When, as is the case for many rivers, the estuary contains broad flats or shoals of mud or sand which are nearly dry at low water, the tide sometimes rises so rapidly, especially if the mouth of the estuary be funnel-shaped, that the wave becomes a wall of water, and is then properly called a "bore." Let us note briefly the way in which Hangchow Bay affords typical circumstances of this sort, so that we there have a most striking case of this interesting phenomenon.

The Physiography of Hangchow Bay

Hangchow Bay, or the estuary of the Ch'ien-tang River, has a very marked funnel shape. From Yangtse Cape (the extremity of Pu Tung Peninsula) on the north to Ketau Point on the south is considerably over sixty miles, while the distance between banks at a point thirty miles farther west is approximately only half of this and in twenty miles more has again been reduced by half, so that along the meridian of Chapu it is only about eighteen miles wide. From Ketau Point in a line approximately northeast there extends for over eighty miles a chain of rugged islands, beginning on the south with Chusan, by far the largest, and ending on the north in the Saddle Group, North Saddle Island being in the same latitude as the low-lying and rounded corner of Yangtse Cape. The most westward group is comprised by the Volcano Islands, which lie approximately due south from Yangtse Cape and about midway across the mouth of the bay. We shall presently refer to this group as one of the places at which definite observations of changing water-level have been made in studying the birth of the bore. Westward of this meridian the bay shoals quite rapidly in the southern half, and at times of low water, west of 121½° longitude (east of Greenwich) the mud drys for two miles from the southern embankment. It was off the northeast corner of this extensive "flat" that H. B. M. ship *Kite* was lost.

But the most marked shoaling and constriction in the figure of Hangchow Bay has yet to be noted. As already stated, at Chapu the bay is about eighteen miles wide. From this point inward the general direction of the bay is southwesterly and safe navigation ends near Rambler Island, which is about eleven miles from Chapu. Here the width of the bay for water over six feet deep has narrowed to less than five miles, and from here on inward for quite a distance the whole estuary, with the exception of a very narrow region near the northern bank, is a sandy shoal. Between Rambler Island and Haining is a range of hills forming a promontory that extends well out, making the general direction of the bay take a quarter turn and bringing it to the northwestward. On this promontory is the town of Kanpu, and a little beyond the projecting point of land and well out in the middle of the channel is a group of low tide-washed islands. Just at the western end of this turn in the northern shore is a sharp indentation, protected by a good-sized hill, which forms Bore Shelter Bay. It is at these flats and along the meridian of this hill that an observer at the Haining Pagoda gets his first glimpse of the bore.

On account of the regular recurrence of the bore, junks going from Chapu road to Hangchow take three days, and shelter first in Bore Shelter Bay and second at Haining platform. Boats drawing over three feet can not be used. The return from Hangchow to Chapu road can not be safely accomplished under three tides in any boat. Thus in spite of being situated on the main tributary of the bay of the same name, the city of Hangchow, the capital of the rich and populous province of Chekiang, the center of a great silk-producing district and of the manufacture of the best silks, being the sole source of the silk fabrics supplied to the Imperial household, and a great center of Chinese culture and literature, has practically no direct connection with the sea. There is a small canal connecting it with Haining, but practically its whole export trade passes through Shanghai by way of the water-route we have already described. In 1905 the total trade of the port amounted to 17,496,980 Haikuan taels.[2] Our interest in these facts in the present connection lies in this: that this ancient and important city, whose population is now about 350,000, owes its very existence toward the southwest to the construction of the great sea-wall, called by the natives the "bore wall."

It is probably true that some thousands of years ago the great flat area now forming a considerable part of the province of Chekiang and Kiangsu was under water and that the Yangtse, gradually increasing its delta, reclaimed the land. The inhabitants, to assist the river in its land-forming process, built sea-walls, using the various islands as corner-stones. The wall or dyke confining the waters of the Haining-Hangchow canal is probably one of these early structures, which has better withstood the ravages of time and tide. As these walls were multiplied and extended, they caused the projecting north point formed by the alluvial deposits of the Yangtse and the Ch'ien-tang Kiang to extend seaward, thus forming the present funnel-shaped mouth of the latter river, as already noted, and obstructing to a considerable extent the progress of the ocean tide, the northern promontory deflecting it inwards and the shoals causing it to heap up into an increasingly powerful wave—the forerunner of the present bore. Against this rush of water the poorly constructed dykes were insufficient and the people along the shores of Hangchow Bay, especially on the northern side, frequently suffered great losses.

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[2] A tael is about five sixths of a gold dollar and is the unit of trade in China.

THE RELATION OF COLOR AND CHEMICAL CONSTITUTION

BY WILLIAM J. HALE, PH.D.

UNIVERSITY OF MICHIGAN

AMONG the many branches of scientific learning whose early development we owe to the analytical mind of Sir Isaac Newton, none can show a more beautiful discovery than that different colored rays of light suffer unequal amounts of refraction or bending when passed through a prism; and that sunlight itself by similar means is resolved into a series of colors, the order of which, beginning at the red and ending with the violet, corresponds with a gradual increase in refraction. It was this that gave us our first spectrum and proved at once the composite nature of white light.

After these discoveries by Newton, a hundred years and more elapsed before Wollaston in 1802 observed the spectrum of a ray of sunlight admitted through a narrow slit in a window-blind. In this simple experiment, which gave a better distribution of the spectrum colors than could be obtained with the pencil-like rays of Newton's time, certain black lines were seen to cross the spectrum parallel to the slit. The investigation of these lines, however, was left to Fraunhofer, who, several years later, with much improved apparatus for collecting the light rays and projecting the same upon a screen, succeeded in definitely establishing the existence of a large number of black lines in the solar spectrum. In other words, the light from the sun was shown to be incomplete by reason of the absorption of certain of its rays, as was indicated by over 700 of these dark lines. To the principal lines, still called by Fraunhofer's name, he assigned letters beginning in the red with A and ending in the violet with H.

That there also existed an invisible portion of the spectrum lying to either side of the visible spectrum, was early pointed out. Sir William Hershel in 1800 observed the great heating effect of that portion beyond the red, while Sir John Herschel in 1840 demonstrated the existence of Fraunhofer lines in this infra-red region. Ritter and Wollaston showed that silver chloride blackened readily in the invisible portion of the spectrum beyond the violet, a fact readily inferred from Scheele's observation in 1777 that silver chloride turned dark more readily in violet than in red light. E. Becquerel, however, in 1842 succeeded in identifying many of the Fraunhofer lines in this ultra-violet region and lettered the principal lines from L to P in continuation of those already lettered by Fraunhofer.

Fraunhofer had noticed that the yellow spectrum line from common salt, when fed into a spirit lamp, was identical in position with the *D*-line of the solar spectrum. But though the formation of these discontinuous spectra from various salts in a flame was generally known, it was not until 1859 that the presence of the Fraunhofer lines in the solar spectrum was clearly explained by Kirchhoff, who deduced the following law: "The relation between the powers of emission and the powers of absorption for rays of the same wave-length is constant for all bodies at the same temperature." Thus the particles of a substance under the excitement of some outside force are thrown into a state of vibration which is dependent upon the chemical nature of the substance itself. This vibratory motion gives rise to waves in the ether and we have the phenomenon of emission. Again the particles of a substance are most responsive to these same characteristic vibrations and will absorb them whenever present, just as, by analogy, the strings of a piano pick up sound waves of the exact period in which they vibrate when these waves are set in motion by other musical instruments in the neighborhood. Kirchhoff explained the solar spectrum as one produced by a strong white light from an interior sphere passing through a concentric layer of vapors of many substances, each of which absorbs those particular rays that correspond to their own periods of vibration. The light, thus deprived of many definite rays, indicated their absence when its spectrum was cast upon a screen by the appearance of dark lines—the images of the slit through which the light passed—corresponding always to the wave-lengths absorbed. It must not be assumed that these lines of absorption are regions of total darkness. The particles set in vibration by the rays absorbed will naturally give out some light of this same vibration period, but the light emitted is so small in comparison with the rays from the original source which pass through unmolested that the image cast upon the screen will give the appearance of almost total darkness.

Now when a substance is yellow in color we can readily ascertain that the spectrum of the light it reflects is lacking in a number of rays of various wave-lengths. These rays correspond to the complement of the color reflected, and in the case of a yellow substance belong to that magnitude found in the blue end of the spectrum. If no wave-lengths of the visible spectrum had been absorbed, we should have had the continuous spectrum of white light in the light reflected, *i. e.,* the body itself would not be colored. Colored substances, therefore, absorb the rays of their complementary colors and, consequently, when white light is transmitted through them their spectra will indicate the regions of this absorption by dark bands of varying intensity. The absorption spectrum coincides always with the spectrum obtained from the reflected light.

Though Fraunhofer had failed to grasp the true significance of the dark lines in the spectrum he was able to solve another highly important question—that of determining the wave-lengths to which these lines corresponded. From the wave-theory of light it may be readily understood that certain ether particles in the courses of different rays of light (*e. g.*, those of equal amplitude) may receive a strengthening or retardation in their transverse vibrations according as they fall in with the same phase of vibration or out of it. Upon this principle of interference of light as developed by Young, Fraunhofer based his method for studying and measuring the lines of the spectrum. He made what he called a grating by ruling close together a number of parallel lines upon a glass plate. When light is thrown upon this series of equal and equidistant apertures a certain amount of the light will be diffracted to either side of the direct course. Among these diffracted rays as collected by a convex lens may be found several series of bright and dark bands which correspond to the points of augmentation and retardation, respectively, of the ether particles under the influence of light from certain apertures. By simple calculation the first bright band is known to be formed when the light rays from two adjacent apertures differ by exactly one wave-length in their respective courses to this band. A ready means, therefore, is given for measuring the wave-lengths of light rays. When white light is used a number of these bright bands will occur, with the light of shortest wave-length —the violet—nearest the central image and that of the longest wave-length—the red—farthest removed. In other words, we have a spectrum, but one so constructed that a direct means is given for determining the wave-lengths of the various lines it may present. The complete map of the wave-lengths of the lines in the visible solar spectrum was published in 1868 by Ångström. The wave-lengths were expressed in ten millionths of a millimeter. Since that time they have served as a standard in all similar investigations under the name of the Ångström Unit (A.U.). One millimicron (the millionth of a millimeter $\mu\mu$) is equal to 10 A.U. The visible spectrum extends from light of about 7,600 A.U. in the red to that of about 3,900 A.U. in the violet. A more satisfactory method of expressing the results of observations in the spectrum is to use the number of waves of any particular ray of light which occur in one centimeter in vacuo, or what is called the oscillation frequency (O.F.). This is the reciprocal of the wave-lengths when reduced to vacuum values. As the reduction makes but little difference in the final value, it is usually customary to make the correction by adding one or two A.U. to the observed wave-lengths. Curves constructed from oscillation frequencies approach more nearly a straight line, and thus are easier to draw.

A few of the best known lines may be given in order to show the relation in values:

Symbol.	Color.	Wave-length. (λ)	1/λ O. F.	Frequency per Sec.
D	Yellow	0.0005893 mm.	1,696	510 trillion.
F	Blue	0.0004862 mm.	2,000	618 "
H	Violet	0.0003970 mm.	2,520	760 "

Our best modern instruments for work in the infra-red region depend entirely on the heating effect. So sensitive indeed is the bolometer, as devised by Langley, that a difference in temperature of one five-hundred-thousandth of one degree F. can be determined and, by its use in this region of the spectrum, rays of wave-length 100,000 A.U. have been detected. The study of the ultra-violet region of the spectrum depends upon the sensitiveness of silver compounds and accordingly on photographical measurements. As glass was found to absorb the rays of shorter wave-lengths than 3,300 A.U., quartz lenses and prisms must be used. Quartz absorbs rays of a wave-length less than 1,850 A.U., but fluorite may be used for rays down to a wave-length of 1,000 A.U. Air itself exerts a powerful absorption for rays of a wave-length of 2,000 A.U. and under, hence for these finer observations the apparatus must be exhausted and observations made in a vacuum. In the photographical determinations of this region the greatest care must be taken in preparing the silver bromide plates. No gelatine can be used upon the plates as it is found to exert a strong absorption for the shortest rays. The sensitive plates are usually made by precipitating silver bromide in a solution over a glass plate and allowing the precipitate to settle slowly upon this plate. When these sensitive films are colored, the plate becomes more sensitive to the rays which the dye absorbs.

The principle established by Kirchhoff was applied with intense vigor to the study of all the lines of the solar spectrum. The introduction of various substances into a flame was found to give spectra of many colored lines, but these were always definite for each and every substance examined. The lines in these discontinuous spectra were seen in many cases to have their exact counterpart in certain of the Fraunhofer lines and consequently the existence of the particular element producing them may be assumed in the solar atmosphere. In this manner, the chemical composition of the sun's atmosphere has been determined, and even new elementary substances discovered therein by the selection of certain lines or groups of lines, unaccounted for by any element previously studied. The line-spectra of many elements are readily obtainable at low temperatures, but for iron and similar metals a far higher temperature is required, as, for example, that of the arc. For gases a strongly induced electric current (one of high tension) is necessary. In the arc spectrum of iron over 2,000 lines are observed, whereas the spectrum obtained at the flame temperature consists of only a few bands and lines. At the hottest portion of the spark the iron spectrum shows the same lines as in its arc spectrum, but in addition a number of "enhanced lines," as Lockyer has chosen to call them. By reason of these latter, Lockyer assumes that the atom of iron (as well as of other elements) may consist of more elementary constituents at extremely high temperatures, and, if the cooler vapors could be removed from this hottest zone, the enhanced lines might stand alone for the elementary form of iron—as a proto-iron. Such conditions are said to be obtained in sun spots and our hottest stars. Whether the extremely high temperature alone is sufficient to produce the enhanced lines, or whether their origin lies in the enormously rapid changes of electric stress, can not be answered at present. In either case, there seems to be no doubt but that the atom of an element consists of yet smaller particles, which, with rise of the disintegrating forces, show a marked increase in their activities, and, owing to the similarity existing between these particles, give spectral lines of greater and greater simplicity.

When a group of lines in a spectrum has oscillation frequencies that obey a single formula we call this group a series. The simplest elements usually give three series, each of which consists of lines in doublets or triplets. The action of a strong magnetic field upon the series of an element's spectrum tends to decompose the series; each line is resolved into two or three lines (doublets or triplets) according as the light is viewed along or across the magnetic lines of force. This is called the Zeeman effect. Of the three components of motion of the particles, that one which lies in the direction of the lines of force with vibrations backwards and forwards can emit no light except when viewed at right angles to these lines of force. The other two motions at right angles to the lines of force suffer a retardation and acceleration, respectively, with the result that their oscillation frequencies are similarly affected and consequently two separate lines will be developed. These may be observed by themselves when the light is viewed along the lines of force or in conjunction with the original line—with position between these two—when the light is viewed across the magnetic field. The electro-magnetic composition of the atom therefore seems to be corroborated by these results.

As an analogy to this gradual disintegration of the atom under the great stress brought to bear upon it, and further to show how the more complex molecules behave under the influence of temperature, we have only to examine the spectrum of a compound. Whatever compound is admitted into a flame, the characteristic spectrum of the molecule first makes its appearance. This consists not of lines, but of bands of varying widths. On further increase of temperature the decomposition of the compound molecule is attained, and the bands gradually give way to the characteristic lines of the elements concerned. With numerous compounds, for example, the metallic chlorides, this temperature is exceedingly low. Since the presence of spectral lines is undoubtedly to be accounted for by the vibrations within the atoms, we may well have recourse to the modern conception of the atom as advanced by J. J. Thomson. Here the atom is considered as made up of a central mass carrying a positive charge. Surrounding it are numerous electrons of a negative charge, the number of which increases directly with the atomic weights of the elements concerned. The electrons are undoubtedly arranged in some systematic order and may, as Nagaoki imagines, follow parallel courses closely analogous to the rings of Saturn. A disturbance of any one group or belt of electrons will undoubtedly produce a disturbance in yet other groups and, according to the amount of disturbance, the definite vibratory motions established will set up vibratory motions in the ether, later to be detected in the spectrum. From this hypothesis the spectrum of an element of high atomic weight might be expected to contain more lines than one of low atomic weight. Such, however, need not necessarily follow. If we take the case of radium, uranium, etc., we may imagine the electrons in its atom to be grouped closely together in only a few courses or belts. In fact this very hypothesis may well account for the discharge of electrons from such highly condensed arrangements and give rise to radioactivity.

From this modern standpoint the molecule is regarded as a combination between atoms as effected by the loss or gain of one or more electrons from one to the other, developing what is commonly termed "bonds of affinity" and corresponding in number to the valence of the particular atoms concerned. These may be more correctly construed as Faraday tubes of force.[1]

With these ideas in mind the banded spectra of compounds may be accounted for by disturbances induced between the atoms, as well as by small electronic vibrations set up in the atoms themselves and due to the perturbances of the Faraday tubes of force. The vibrations resulting from this composite arrangement of vibratory centers may be sufficient to extend over a considerable area of wave-lengths and thus produce a band. As the temperature increases these band spectra, always obtained with compounds, pass over gradually into the line spectra of the constituent elements concerned. There follows, then, with increase of temperature or electric stress, as has already been noted,

[1] The lines of force binding two atoms and constituting an electrical field between these charged atoms is conveniently regarded as made up of tubes of force, each with its positive electrical charge at one end, the beginning of this tube, and its negative and equal electrical charge at the other end or termination of the tube. Each Faraday tube, therefore, encloses a charge of electricity of unit value or that denoted by one single electron and consequently an atom that is univalent must enter into combination by means of one Faraday tube of force, one that is bivalent by two such tubes, etc. The positive atoms are those formed by the loss of electrons and the negative atoms are those which can take up these same electrons.

a gradual disintegration of the series of lines into simpler arrangements, caused probably by reason of a similarity existing between the ultimate constituents of our elements. This explanation is made more plausible from a study of the Zeeman magnetic effect upon similarly charged particles.

Even under the ordinarily obtainable conditions of the laboratory a great similarity may be noted between the series of lines in the spectrum of one element and the series of all other elements belonging to the same family. Thus with a gradual increase in atomic weights there occurs a corresponding gradual shifting of the series toward the red end of the spectrum. Increase in atomic complexity is ever seen to have a marked effect upon the vibratory motion of the simplest particles such that vibratory frequence is retarded. Among compounds, as well as with the elementary substances, this influence of mass is clearly shown in their spectra. Owing to the great tendency among most compounds to undergo ready decomposition when heated an examination of their spectra is restricted to the absorption spectra alone. The relations for absorption spectra having already been noted, it need hardly be further stated that the absorption bands in the spectra of compounds indicate at once the color of the compounds themselves and, what is most important of all, anything that can be brought to bear upon the interpretation of these bands and their positions should give us an insight into the cause of color as existent among compounds generally. In the examination of absorption spectra of compounds, the best results are obtained when the substances can be dissolved in some solvent which exerts but little or no absorption action for light. Among the best examples of such solvents are water, methyl alcohol (wood-spirit), and ethyl alcohol, none of which will absorb rays of a wave-length over 2,000 A.U. The absorption spectrum of a compound dissolved in a medium of this nature is identical with its absorption spectrum observed in the free state.

Among the first to obtain any positive results whatsoever in the examination of the absorption spectra of compounds was W. N. Hartley. He studied the solutions of metallic nitrates and found that the absorption in these cases was slightly modified with increase in atomic weight of the metal present, and concluded, therefore, that that portion now termed the nitrate ion—or negatively charged portion of a nitrate when dissociated by a solvent—has no effect upon the band. Not, however, until 1879, when Hartley and Huntington turned their attention to the study of absorption bands in the ultra-violet regions of the spectrum, could any hypothesis of a definite nature be formulated as regards the relation of these bands to chemical constitution. Their method of observation, which has been in use up to the present time, depended entirely upon obtaining a series of photographs of the spark spectrum as viewed through layers of a solution at varying concentrations. Hartley and Huntington used a cadmium alloy, which they found to give a great number of lines, but in recent work the arc spectrum of iron has been adopted. This latter gives, as already noted, a vast number of lines extending throughout the visible and invisible spectrum in a more or less equally distributed manner. The presence of an absorption band is detected by the absence of lines in the photograph, hence the advantage of their great number and equal distribution. By successive photographs accompanying an increase in dilution the greatest degree of absorption, and thus the head of any particular band, may be observed.

The oscillation frequencies at the edges of these bands were determined up to the point of complete transmission following the increase of dilution. The figures obtained were plotted as abscissæ against the corresponding volumes in which definite amounts of the substances were dissolved. The curved lines drawn through these points, called by Hartley the "curves of molecular vibrations," were found to be closely related to the chemical constitution of the compound studied. More recently a better method of plotting results consists in photographing through varying thicknesses of a solution of known strength and then diluting the solution ten times, repeating the observations, again diluting ten times, and so on till the point of complete transmission is reached. The relative thicknesses are now expressed in millimeters of those thicknesses that would be required of the last or most diluted solution, and these values plotted in the form of logarithms as the ordinates over against the oscillation frequencies as abscissæ. Curves thus plotted show at once the same relative shift with the ordinates as is made with the thicknesses examined. The persistence of a band, or change of concentration through which a band asserts itself, is well illustrated by this curve. In this point—the persistence—we have a characteristic function of the bands which connects them closely with chemical properties.

The compounds studied have been entirely within the realm of organic chemistry. In this class we meet with the most pronounced and, at the same time, the most easily varied tints. A study of these variations in color in the closely related organic compounds has, up to the present, occupied the entire attention of investigators, among whom, after Hartley and Huntington, are to be named Baly, Desch and Stewart.

The absorption spectra in the ultra-violet region may be classified under two broad types; the first type is that in which only a general absorption is present; the second is that in which distinct absorption bands occur, a type usually defined as one of selective absorption. To the first class belongs, broadly speaking, the majority of the aliphatic or open chain compounds; to the second belongs the majority of the aromatic compounds or those of ring structure. Among the first observations made it was discovered that an acid and its alkyl ester (esters formed by such groups as methyl, CH_3, ethyl, C_2H_5, etc.) gave identical absorption bands; a fact that pointed conclusively to the identity in molecular constitution existing between the two compounds. But among the most interesting cases bearing upon the relation of these absorption bands to chemical constitution stand the two substances acetyl acetone and ethyl aceto-acetate. We assume that each of these compounds can exist in either of two forms—one in which an oxygen atom is doubly linked to a carbon atom which bears in turn two carbon radicals and thus forms a so-called ketone; the other, where this same oxygen atom is singly linked to the carbon atom in question and has its second affinity absorbed in a hydrogen atom, thus forming a so-called hydroxyl derivative, or one usually designated by the term enolic. The two forms may be graphically represented thus:

Ethyl Aceto-acetate.

$$\begin{array}{ccccccc} CH_3 & - & C & - & CH_2 & - & C=O \\ & & \Vert & & & & | \\ & & O & & & & OC_2H_5 \end{array} \qquad \begin{array}{ccccccc} CH_3 & - & C & = & CH & - & C=O \\ & & | & & & & | \\ & & O & & & & OC_2H_5 \\ & & | & & & & \\ & & H & & & & \end{array}$$

(Ketonic) H (Enolic)

Acetyl Acetone.

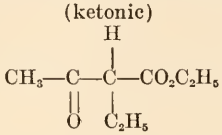
$$\begin{array}{ccccccccc} CH_3 & - & C & - & CH_2 & - & CO & - & CH_3 \\ & & \Vert & & & & & & \\ & & O & & & & & & \end{array} \qquad \begin{array}{ccccccccc} CH_3 & - & C & = & CH & - & CO & - & CH_3 \\ & & | & & & & & & \\ & & O & & & & & & \\ & & | & & & & & & \\ & & H & & & & & & \end{array}$$

(Ketonic) H (Enolic)

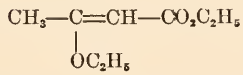
Such compounds are described as tautomeric, *i. e.*, they contain a labile atom, hydrogen, which in its wandering or change of position brings into existence two distinct modifications of a compound without altering its general structure. As this change is not complete at any one instant and may vary with change of conditions, we have a condition of equilibrium always existing between the two forms. In the compounds just cited the labile hydrogen atom may be replaced by the atom of a metal and thus give what are called metallic derivatives, which from chemical evidence are supposed to exist entirely in the enolic form. Upon examination of the absorption spectra of these compounds, acetyl acetone itself, as well as its aluminium derivative, was found to give similarly banded absorption, but with that of the aluminium salt showing a greater persistence. Now ethyl aceto-acetate gives only a slight general absorption without trace of a band. Its aluminium derivative, however, gives a banded spectrum which bears a great similarity to the spectrum of acetyl acetone. Therefore, if the metallic salts are enolic, as chemical evidence strongly favors, the free ethyl aceto-acetate certainly must be ketonic.

In order to investigate this matter more closely the two ethyl derivatives of ethyl aceto-acetate were examined. These compounds made by entirely different processes have different properties and correspond in constitution to the two distinct forms, ketonic and enolic, of the free ethyl aceto-acetate. They may be graphically represented as follows:

Ethyl ethyl-aceto-acetate (ketonic)

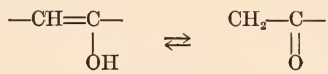


Ethyl β-ethoxy-crotonate (enolic)

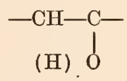


Upon examination of their absorption spectra, it was observed that the enolic compound exerts only a general absorption without a band, while the ketonic compound was practically free from absorption. This is exactly what might be anticipated from the results of Hartley, who had already shown that no difference exists between the absorption spectrum of the compound and that of its alkyl (here ethyl) derivative. Even a mixture of these two alkyl derivatives fails to show the presence of absorption bands in the spectrum. We may conclude, therefore, that an absorption band is not to be attributed to either the one or the other form of a tautomeric substance, but rather to the changing of one form into the other—a dynamical isomerism. If this intramolecular transformation is the source of the disturbance which produces the absorption bands, then an acceleration of this transformation should show itself in the increased persistence of the band, while retardation of the same should diminish this persistence. For some time it has been known that alkalies exert a marked positive influence upon the velocity of tautomeric changes and, as may be naturally inferred, acids retard this change. On the addition of a small amount of sodium hydroxide to a solution of ethyl aceto-acetate, the form of the absorption-curve changes at once and a band appears. On the further addition of alkali, the depth of this curve, that is the persistence, increases until it reaches a maximum corresponding to the presence of a large excess of alkali. The absorption-curve of the aluminium derivative of this ester has not the persistence of that of the sodium salt when the sodium hydroxide is present in excess of one molecular equivalent. With the addition of hydrochloric acid a retarded action is developed and even the absorption curve for the free ester is seen to diminish slightly in its persistence when an excess of acid is present, indicating, therefore, that the free ester is not entirely ketonic, but is in equilibrium with a very small quantity of its enolic modification. Spectroscopic evidence points out that the persistence of the absorption bands over concentration changes is directly proportional to the number of molecules in the state of oscillation or, in other words, is a measure of the dynamical isomerism between substances in equilibrium with each other.

From these considerations it is evident that this dynamical isomerism must be closely connected with some peculiar vibration or free period synchronous with the oscillation frequency of the light rays absorbed. The oscillation frequency, however, is about the same for all the substances just examined and lies between the limits 3,600 and 3,800, no matter what the labile atom may be. We are, therefore, forced to the conclusion that the absorption bands can not be due directly to this oscillating labile atom, or, in other words, the vibration frequency of this atom is not identical with the oscillation frequency of the light absorbed. This inference is strongly substantiated by physical evidence which represents atomic motion as far less than that of this magnitude of light rays. There remains then but one final solution of this question, or the conclusion that the absorption band is due directly to the change of the linking which accompanies the wandering of the labile atom. In the case of the keto-enol tautomerism just discussed, we may represent the change graphically as follows:



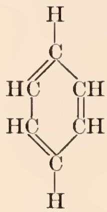
At some stage in its transformation the hydrogen atom must have wandered to the half-way point of its journey and have been linked definitely to neither the carbon nor the oxygen atoms. We should then have the phase in which the carbon and oxygen atoms change linking.



By the examination of countless numbers of organic compounds it is found that absorption bands in the ultra-violet region of the spectrum are shown only by compounds exhibiting some form of tautomerism, whether this be due to the keto-enolic type or to a periodic type, like that present in ring compounds. The oscillation frequency of the light absorbed in all cases of keto-enol tautomerism is about the same, but with an increase in the mass of the molecule as brought about by the displacement of one atom by a second atom or group of atoms of greater relative weight, a decrease in the oscillation frequency is observed. This displacement, however, is only small and does not interfere with the general assumption that there is present some condition common to the whole group upon which the absorption directly depends.

From the standpoint of modern theories regarding the structure of the molecule, there must arise in this tautomeric change a constant making and breaking of the Faraday tubes of force. This means a constant disturbance of the electron systems and, consequently, similar vibrational disturbances in the ether. From Hewitt's studies in fluorescence these electronic disturbances, due to dynamic isomerism, appear to be of the same order as light waves and, consequently, by absorption of their wave-lengths white light should show the absorption spectra we have noted. The sodium and aluminium derivatives of ethyl aceto-acetate may be described as equilibrium mixtures of the enolic and ketonic forms. The fact that the sodium salt is so easily hydrolyzed in an aqueous solution need not enter into the discussion of the absorption spectra. The evidence in all these cases goes to show that the metallic ion still exerts its influence and does not lead an altogether separate existence from that of the negative ion. Accordingly we may regard the Faraday tubes of force as stretched, but not necessarily broken, by the action of the solvent. On this basis, an ionizing solvent is to be considered as one that will bring about this lengthening of the Faraday tubes. Among the best examples, we may cite water, liquid sulphur dioxide, and liquid ammonia, or those substances which possess in reality a certain amount of "residual affinity"—affinities that may yet be exerted. Tautomeric changes in solution receive their interpretation, then, in the lengthening of the Faraday tubes of force to that point where the labile atom comes so far under the influence of a neighboring atom that a break occurs, which in turn gives rise to the oscillatory disturbances already discussed. With tautomeric compounds in which the labile atom has been replaced by an alkyl group there is absence of tautomerism due to the non-formation of alkyl ions, in which case it is seen that water and alcohol have not sufficient power to lengthen the Faraday tubes of force. The persistence of an absorption band may be defined now as the measure of the atoms in this transitorial state or the measure of the extent to which the labile atoms are separated from the molecule proper. Wherever the tautomeric compounds display the phenomenon of fluorescence a second free period of vibration is present. The latter must depend upon the former since a compound does not fluoresce except when exposed to light rays of the frequency of the first free period. Recently it has been demonstrated that a fluorescent substance gives two bands in its absorption spectrum, one for each of these periods of vibration. The band from the incident light is well marked, but the band from the fluorescent light is so faint that it can be made fairly visible only when the light of the first free period is strengthened; a fact that substantiates the dependence of the second free period upon the first.

As the origin of absorption bands in the ultra-violet spectrum have received an explanation in the change of linking brought about by the shifting of a labile atom, so clearly represented in the examples of keto-enol tautomerism, we may rightly expect to find absorption bands in the spectra of other compounds in which some change of linking is exhibited. No more beautiful example can be found than that of the compound known as benzol, where six carbon atoms, unchangeable in their order, are bound together in a single ring. To each carbon is attached an atom of hydrogen, but as carbon is usually considered quadrivalent, a fourth seemingly unused bond of affinity remains free to each of these carbon atoms. This affinity may be considered as the residual affinity. To this substance Kekulé has assigned the structure illustrated by the graphical formula:

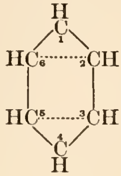
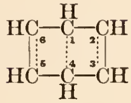
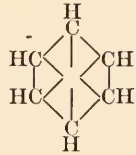


The introduction of three double linkings between the alternate pairs of carbon atoms satisfies the demands for quadrivalence in these atoms. But Kekulé clearly called attention to the fact that a sort of equilibrium existed between all the carbon atoms, such that the presence of one of the three double linkings between any two adjacent carbon atoms, when both were involved in the formation of a derivative, would not necessarily change the properties of the derivative from that one formed when two adjacent carbon atoms were united by only a single bond. Now the Kekulé formula, and in fact all the older formulæ assigned to this compound, represent only particular phases in the motions of the molecule. The space-formula proposed by Collie,[2] in which the atoms are represented as in a state of continual vibration, serves well for the basis of our modern conception. Upon examination of the absorption spectrum of benzol we note the presence of seven distinct bands all quite similar and closely situated with reference to each other, appearing between the oscillation frequencies 3,725 and 4,200. These bands are in that part of the ultra-violet spectrum where the absorption bands due to keto-enol tautomerism displayed themselves. At once the idea of a similar make-and-break of linkings between the carbon atoms suggested itself, and, in exact accordance with this hypothesis, the seven distinct bands may find here their cause of formation.

In keto-enol (aliphatic) tautomerism an even number of carbon atoms is always involved in the make-and-break of linkings. Accordingly with the benzol molecule we may assume that two, four or six carbon atoms may enter into this phase at one time. If the carbon atoms are numbered consecutively from 1 to 6, we should have in order the following conditions which represent the change of linkings between certain numbered carbon atoms: (1 and 2), (1 and 3), (1 and 4), (1 and 2, with 3 and 4), (1 and 2, with 3 and 5), (1 and 2, with 4 and 6), (1 and 2, with 3 and 4, with 5 and 6). At the outset we shall suppose the benzol ring to be elastic and capable of under-

[2] *Chem. Soc. Trans.*, 71, 1013, 1897.

going various pulsations, such as may be illustrated by the accompanying figures:

(*a*)  (*b*)  (*c*) 

The dotted lines show the linkings developed from the free affinities when the ring is pulsating between the two forms (*a*) and (*b*). The centric formula for benzol (Baeyer's), as shown in (*c*), may be, therefore, an intermediate form for all the possible forms. The free or residual affinity possessed by each carbon atom asserts itself under the various conditions which can be brought into existence by these pulsations, with the effect that the several linkings produced must involve always a pair of carbon atoms and then in turn during the second stage of the pulsation must suffer a break and consequently give rise to some particular one of the seven possible phases, with its characteristic absorption band of course depending upon the carbon atoms in question. Altogether, when the entire ring is free to pulsate in every direction, there will arise seven absorption bands which represent the seven possible combinations of linking-change.

The derivatives of benzol may be expected to show some variation in type and manner of pulsation from that of the parent ring, but whatever changes occur the effect upon the characteristic absorption spectrum of the original molecule will always indicate the exact nature of each change. In this connection it will be well to consider a few of the more important derivatives, which, as is generally known, are primarily formed by the replacement of one or more of the hydrogen atoms by an equivalent atom or group of atoms—a process called substitution. The alkyl radicals (methyl, ethyl, etc.) stand as a type of the neutral groups and consequently, when they are present, little change in the spectrum of the original substance should be observed. The spectrum of toluol, $C_6H_5 \cdot CH_3$, ethyl benzol, $C_6H_5 \cdot C_2H_5$, etc., are almost identical, but only the first two absorption bands of the original benzol spectrum are well marked, the remaining bands having fused more or less into one broad band. With aniline, $C_6H_5NH_2$, where the basic unsaturated amido-group (NH_2) has replaced the hydrogen atom, we get only a broad absorption band caused, no doubt, by the residual affinity of the nitrogen atom which binds or holds all the free affinities of the benzol ring. Upon the addition of an excess of hydrochloric acid to aniline, we obtain the saturated compound known as aniline hydrochlorate, $C_6H_5 \cdot NH_3Cl$, the nitrogen having passed from the trivalent to the quinquivalent state. This compound, as might be anticipated, gives an absorption spectrum resembling very closely that of the mono-alkyl derivatives of benzol just mentioned.

The absorption band of phenol, C_6H_5OH, differs from that of the mono-alkyl derivatives in that one pronounced band has replaced the two prominent bands in the spectra of the latter. In the case of anisol, $C_6H_5 \cdot OCH_3$, the methyl derivative of phenol, known as an ether, the two prominent bands are again in appearance. In other words, the substituting group methoxyl (OCH_3) partakes more of the nature of a saturated alkyl group, whereas the hydroxyl group (OH) acts very differently. By a close examination of the two bands from anisol and the one from phenol we see that the transmitted portion, or that portion which serves to divide the one band into two, lies between the oscillation frequencies, 3,640–3,655. This is exactly the region where the absorption bands due to keto-enol tautomerism make their head. In other words, the presence of just such dynamical isomerism as may be caused by the wandering of the labile hydrogen atom of phenol will account for this absorption band and its position in overlying the regular bands due to phenolic structure, as shown in the case of anisol, etc. That a condition of dynamical isomerism is really present in a free phenol is further proved by the shifting of the absorption band to the left upon the addition of sodium hydroxide to its solutions; a result always observed in keto-enol tautomerism. Upon the bands formed by anisol the addition of alkali has no effect. On the other hand, the addition of hydrochloric acid to a phenol retards this tautomerism and when large excess of the acid is used the transmitted portion of the spectrum or that which is due to the free benzol nucleus begins again to make its appearance. The spectrum observed in the case of nitrobenzol, $C_6H_5 \cdot NO_2$, and other derivatives, where the substituent possesses marked residual affinity (due here to the oxygen atoms) shows only a general absorption. This condition, therefore, is brought about when the active residual affinity of the new groups restrains or locks up the free affinities of the benzol ring and thus retards its internal motions.

As with the mono-derivatives of benzol, so also with the disubstituted derivatives, the general rule holds true; wherever the substituents are groups well saturated, they will exert scarcely any retarding action upon the pulsations of the original molecule. The disubstituted derivatives are classified as ortho, meta and para, according as the groups are adjacent, once removed, or twice removed (diametrically across the ring) respectively, from each other. The para compounds give a spectrum more closely resembling that of the parent substance, benzol, and hence may be said to be the more symmetrical arrangement, or that which accords best with the even or symmetrical pulsations of the benzol molecule. With the ortho- and meta-compounds we may say that the unsymmetrical loading of the ring operates against the even pulsations and tends to produce irregular vibrations which give rise to less distinctive absorption bands.

In aliphatic, as well as in aromatic, compounds, we often observe that a certain amount of residual affinity lurking in the oxygen atoms can exert a strong influence upon an entire group of atoms. One of the simplest and most reactive combinations in which oxygen may be found is that known as the carbonyl group (CO), which, when occurring between two carbon radicals, constitutes a ketone as we have already noted. The simplest ketone is acetone, $CH_3 — CO — CH_3$. The additive capacity of this carbonyl group for various reagents is well known, but this capacity very often decreases in power with an increase of the molecular aggregation in the near vicinity. For example, the additive capacity of the carbonyl group in the compound methyl-ethyl ketone, $CH_3 — CO — C_2H_5$, is usually less than that in acetone. These and similar facts have been explained upon the hypothesis of "steric hindrance" for lack of a better phrase. Though at times this hypothesis may best explain some of the intricate problems, still it hardly dare be supposed that the paths of intra-molecular vibration of the atoms is other than large in comparison with the size of the atoms themselves; consequently, slight increase in the mass of the substituents should have no appreciable effect upon the activity of a neighboring group. Oftentimes it was found that very large substituents increased the additive capacity of a carbonyl group. Thus when one of the hydrogen atoms of acetone is replaced by a carbethoxyl group ($COOC_2H_5$), a group formed by the replacement with ethyl of the hydrogen atom in the regular organic acid group, carboxyl (COOH), we get a great increase in the activity of the original carbon group. The compound so formed would have the formula, $CH_3 — CO — CH_2 — COOC_2H_5$, *i. e.*, ethyl aceto-acetate—the very same compound as was studied with reference to keto-enol tautomerism. An explanation of the increased activity in this case from the standpoint of dynamical isomerism which may be present seems to be most adequate. The oxygen atom exists temporarily in the enolic (OH) stage and the hydrogen atom, at the moment of departing, must leave the oxygen atom and consequently the carbonyl group nascent, *i. e.*, in an exceedingly active form, similar here, no doubt, to the state acquired by ionization in solution. Again the hydrogen atom itself at the moment of separation would be most susceptible also to chemical action.

In order to get an idea of the relation of this carbonyl group to the carboxyl group, one of the simplest compounds which exhibits this arrangement was studied. The example taken was the ethyl ester of pyruvic acid, $CH_3 — CO — COOC_2H_5$. Here there was observed an absorption band lying much nearer the red end of the spectrum than that obtained in the case of ethyl aceto-acetate. The band had a head at about the oscillation frequency 3,100, whereas the band of the latter had a head near the oscillation frequency 3,700. As the molecule is lighter than that of ethyl aceto-acetate, we should, from previous observations, expect the band to be shifted farther from the red; the opposite, however, is true and the only explanation that seems possible is that the band is the result of a new kind of vibratory motion arising between two carbonyl groups when in close proximity to each other. In order to substantiate these conclusions other derivatives containing two carbonyl groups were studied. But as the carbonyl group in carboxyl has not all the characteristics of a true carbonyl group, attention was turned to the compound diacetyl, $CH_3 — CO — CO — CH_3$. Here the absorption band occurs at the oscillation frequency 2,400 (wave-length 4,170 A.U.), which is in the visible blue region of the spectrum, and hence this absorption of colored rays must result in the compound itself taking on the complementary color—that of yellow. In the same way it can be shown that glyoxal, OHC — CHO, gives an absorption band in the visible blue region, and consequently its distinct yellow color may be explained. Oxalic acid, HOOC·COOH, however, with a hydroxyl group next to each carbonyl group and therefore analogous to pyruvic ester, gives no band in the visible spectrum, and is, therefore, colorless.

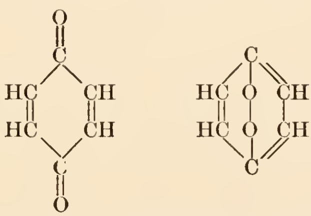
Upon the theory that a change in linking produces the absorption bands, the only possible explanation would be indicated as follows:

The make-and-break contact between the oxygen atoms would give marked activity to these atoms. Such a process other than tautomerism, where a wandering of a labile atom is suggested, has been named by Stewart and Baly[3] "isorropesis" (equipose), and differs from the former in that the head of its absorption band lies much nearer the red end of the spectrum or almost in the visible violet region. With the diketone known as benzil, $C_6H_5 — CO — CO — C_6H_5$, an absorption band with head at the oscillation frequency 3,900 was noticed in solutions of small concentrations. This would seem to indicate the presence of a certain amount of oscillation due to the benzol nucleus. The residual affinities of the two carbonyl groups are undoubtedly fixed, to some extent, by the free affinities of the benzol molecule, but even so there may be present a small amount of isorropesis between the two carbonyl groups. That such is really the case is demonstrated in solutions of greater concentration by the presence of a very shallow absorption band with head at the oscillation frequency 2,650. Its shallowness, however, argues for only a slight isorropesis; indeed the color of benzil, which is but faintly yellow, may be made to disappear entirely

[3] *Chem. Soc. Trans.*, 89, 498, 1906.

upon dilution of its solutions, a fact confirming the spectroscopic evidence of oscillations due to benzol structure in solutions of small concentration. The presence of isorropesis, here brought about by two carbonyl groups in juxtaposition and indicated, as we have seen, by vibratory frequencies in the ether of longer wave-lengths than those due to keto-enol tautomerism, stands out at once as the source of color in chemical compounds. Again we note that the more pronounced this isorropesis the more active chemically are the groups undergoing the disturbance. The additive capacity of benzil is markedly less than that of diacetyl.

Among the compounds which furnish us with examples of this nature, or substances in which two carbonyl groups can come under the influence of each other, we may mention the most important of all, that of para-benzoquinone. This quinone is a derivative of benzol in which two oxygen atoms are located in the para-position to each other. In order to satisfy the bivalence of the oxygen atoms, the para carbon atoms are regarded as having their free affinities absorbed in these oxygen atoms, leaving the remaining carbon atoms to arrange their free affinities in two pairs of double linkings (according to the Kekulé hypothesis). It may be, however, that the second affinity of each oxygen atom will assert itself in a linking between these two atoms and therefore leave the characteristic benzol nucleus undisturbed. The two forms may be graphically shown as follows:



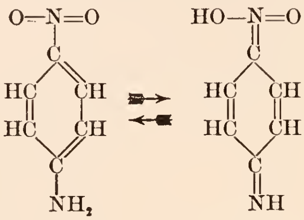
Now it has been proved chemically that para-benzoquinone can exist in each of these two forms. We have then just such an example of making-and-breaking as has been indicated in isorropesis, but in addition a change in the manner of linkings in the molecule accompanies this process. The absorption spectrum of para-quinone gives a band with its head at the oscillation frequency 2,150, one almost identical with that obtained from other ring compounds, *e. g.*, camphorquinone, where two carbonyl groups are adjacent. From a study of the pulsations of the benzol ring the para-positions have been shown to be closely related, and in fact so well brought under the influence of each other as to be considered as practically adjacent. Since the position of the absorption band is in the blue region color must, of course, be present in this substance. Simple quinones usually show a yellow to an orange color. This color is undoubtedly due to isorropesis and whenever we have this class of substances—known as quinones—

as the base of various derivatives, we have a right to look for this same influence between the unsaturated groups, or that condition which gives rise to isorropesis and hence to color. A great portion of the coloring products known have just this sort or structure and the origin of their colors, therefore, may receive the interpretation indicated.

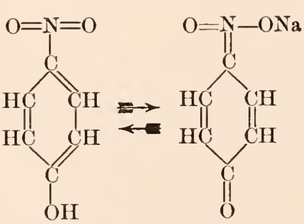
For many years the color theory proposed by Witt has been the basis of all chemical investigations in this domain. Here it is supposed that the color of an organic compound depends upon the presence of an atomic group known as a chromophore, such, for example, as the nitro group (NO_2), etc., and the introduction of more and more of these groups into a compound produces a gradual increase in depth of color. The various radicals with their respective color-giving groups are known as chromogens; upon union of these with other radicals of an acidic or basic character, we arrive at the conditions for coloring products or dye-stuffs. Now the carbonyl group alone does not appear as a pronounced chromosphere, but when two carbonyl groups, as in the ortho- or para-position in the benzol ring, are present one of the best of chromophores is developed. From such results as these Armstrong was led to believe that the particular linkings present in the benzol ring when two carbonyl groups were para to each other might account for the pronounced color reaction shown by these compounds. He characterized this type of structure, wherein the para carbon atoms have double linkings with the oxygen atoms as "quinonoid" (quinoïd), in contradistinction to that of the alternate double linkings in a benzol ring or "benzenoid" (benzoïd). Eventually, he came to the conclusion that color in an organic compound depends upon the presence of this quinoïd arrangement. From the chemical standpoint Armstrong had advanced upon solid ground. The real insight, however, into the relative value of one arrangement over that of another, as to their respective powers of light absorption and consequently of color production, must rest upon spectroscopic evidence. For example, we have seen that double linkings in themselves do not possess any power for light absorption. Their mere presence, therefore, can not account for color in a chemical compound, but if by their presence some form of oscillation is produced, we may expect the establishment of definite vibrations in the ether, which will be possible of detection in the spectrum. In compounds of the quinoïd type the conditions are precisely those that will produce vibrations in the ether corresponding in wave-length to portions of the visible spectrum, consequently the appearance of color. In compounds of the benzoïd type alone the oscillations correspond to vibrations of such frequencies that they fall in the ultra-violet region of the spectrum, and hence such compounds will be free from color. The oscillations which exist whenever the quinoïd type of compounds is concerned, and which distinguish this type from that of the benzoïd, must be due to the oxygen atoms in the para-position. Now the activity of these oxygen atoms is to be attributed to the residual affinity which each is known to possess, and hence by the assertion of this affinity when in close proximity to each other, followed quickly by a break in the same, we arrive at the condition known as isorropesis, upon which form of oscillation the color depends. It is necessary in this process that the active groups undergoing isorropesis should be adjacent. The pulsations of the benzol ring readily furnish the means by which the two para-atoms are successively brought under the influence of each other, and hence their positions will approach more nearly to that of adjacent atoms, a point that was confirmed by the similarity in the absorption spectra between para-benzo-quinone and compounds where the two carbonyl groups were actually adjacent. The study of ortho-quinones falls in the same category as the para-quinones and may be explained in a similar manner. Meta-quinones, however, can exist, but momentarily on the hypothesis of the benzol pulsations and hence are unstable.

Isorropesis, as has just been indicated, occurs between adjacent atoms possessing residual affinity. It is also to be remembered that some disturbing force must be brought to bear upon these atoms, for otherwise no make-and-break and consequently no oscillation can take place. In the simplest case studied, that of diacetyl ($CH_3 — CO — CO — CH_3$), the disturbing influence rests undoubtedly with the hydrogen atoms of the methyl groups which from their electro-positive nature exert a strong attraction for the electro-negative atoms of oxygen. This constitutes a sort of keto-enol tautomerism, the presence of which should certainly be accounted for in the appearance of the absorption-curve; indeed, the slight extension of the absorption-curve of this compound near the oscillation frequency 3,800 corresponds exactly to the location of a band due to keto-enol tautomerism. The cause of isorropesis in a compound rests, then, upon the disturbances of the residual affinities of the two atoms in juxtaposition. In the examples already cited, those of pyruvic acid and oxalic acid, the hydroxyl group is next to the active carbonyl group. The slight positive nature of the hydrogen atom in this capacity will diminish its disturbing effect upon the second oxygen atom, or that of the carbonyl group, and consequently only the slightest amount of isorropesis will be possible. With the alkyl ester of pyruvic acid the conditions will favor a slight isorropesis, as we have seen, but with oxalic acid there should be none at all. In quinones the residual affinities of the benzol ring constitute the disturbing factors. The hydrogen atoms of the benzol molecule may also exert some disturbance. In general, we may say that the amount of isorropesis must rest upon the disturbing influences which can be brought to bear upon the active groups showing residual affinity, or those susceptible of this new kind of oscillation.

Isorropesis need not always be confined to residual affinities between two oxygen atoms. Other unsaturated atoms may show similar reactions. Thus the nitro-anilines, $H_2N — C_6H_4 — NO_2$, give an absorption-curve similar to that of para-benzoquinone. Here the residual affinities of the nitrogen atoms are disturbed by the motions of the benzol molecule. And, in addition, the unsaturated oxygen atoms of the nitro-group are disturbed by the hydrogen atoms of the amido-group (NH_2). These facts, together with the position of the absorption band, point unmistakably to isorropesis, and the two distinct forms thus in equilibrium may be represented by the following figures:



A solution of nitro-aniline in hydrochloric acid gives a colorless solution showing no trace of absorption band to indicate isorropesis. The structure of the hydrochlorate, therefore, is purely benzoïd in type and enters not into the quinoïd form by reason of the saturation of both nitrogen atoms. In the case of the nitrophenols similar reasoning may be followed. The absorption band of para-nitrophenol, $O_2N — C_6H_4 — OH$, in neutral alcoholic solution, is identical with that of para-nitroanisol, $O_2N — C_6H_4 — OCH_3$, the methyl ether of this phenol. Consequently their structures may be assumed to be identical. When the phenol, however, is converted into the sodium salt its absorption-curve alters and a band similar to the band of nitro-aniline appears in the visible blue region of the spectrum; in other words isorropesis has been brought about with the natural consequence—the appearance of color in the compound. The hydrogen atom of the free phenolic group (OH) is seen to be but slightly affected by the residual affinities of the oxygen atoms of the nitro-group; the more electro-positive sodium atom, however, shows a greater activity and may be drawn over to one of the oxygen atoms of the nitro-group, and thus a quinoïd type of linking established. In the equilibrium between



these two forms we may unquestionably look for the conditions which underlie the formation of color in the salts of nitro-phenols. The colorless free nitrophenols present only the regular form of vibration known to the benzoïd structure and hence can give no oscillation of a frequency low enough to produce color. In the salts of these phenols, however, the quinoïd type is developed and, though always in equilibrium with a certain amount of the benzoïd type, isorropesis will be present to an extent dependent upon the degree of unsaturation of the atoms, and indicated by the appearance of color. In the case of meta-compounds a measure of the persistence of their absorption bands indicates a smaller amount of isorropesis and consequently they will be less colored than the ortho- and para-derivatives. In all of these investigations care must be used in the selection of a proper solvent. Since water is known to possess a large amount of residual affinity its action upon the ethers of nitro-phenols will be quite apparent. Alcohol serves the purpose here because it is well known to exert little or no ionizing action upon ethers and esters. In general, the new free period of oscillation—isorropesis—may be represented by the equilibrium:

$$\begin{array}{ccccc} R_1\text{—}C & \text{—} & C\text{—}R_2 & & R_1\text{—}C & = & C\text{—}R_2 \\ \Vert & & \Vert & \rightleftarrows & | & & | \\ X_1 & & X_2 & & X_1 & \text{—} & X_2 \end{array}$$

These are conditions which accord entirely with certain known chemical facts.

In compounds of the benzol structure the cause of color begins with the particular vibrations of the molecule itself. These oscillations, however, as has been seen, are synchronous with light waves of a very high frequency and give rise to absorption bands in the ultra-violet region only. When some other influences can be brought to bear upon these movements, as, for example, the introduction of a potential keto-enol tautomerism, isorropesis is established and the oscillations, which are now of a less frequency, may be low enough to show the beginning of color. When the retardation of these oscillation frequencies is continued, as, for example, by the introduction of heavier atomic complexes for the simpler and lighter hydrogen atoms, the absorption curves due to oscillation will gradually be made to travel toward the red end of the spectrum and the color, naturally, will travel into the blue. A very well-known example of this is the increase in depth of the blue color possessed by certain dyes which accompanies an increase in the number of methyl groups introduced into the molecule. The introduction of a chromophore group, one of a more or less unsaturated nature, may in this light be considered as among the best to push back the oscillation frequency. But with reference to the powerful effect these chromophore groups have upon the retardation of the pulsations of the molecule and the consequent establishment of a new type of linking always in equilibrium with that of the original nucleus, the interpretation of their influence seems best explained in the production of an entirely new, free period of vibration—isorropesis—within the molecule itself. Now the term isorropesis is used to define the oscillation that takes place between the residual affinities of atoms in juxtaposition. The idea, however, may have already presented itself that in the case of the benzol structure the presence of keto-enol tautomerism with its particular period of vibration together with the oscillations occurring in the benzol nucleus, might, by a mutual combination of these two periods, give a period of greater wave-length and thus coincide with light rays in the visible region of the spectrum. If this were true, then these two conditions just stated might be looked upon as potential color systems. The actual presence of the conditions for isorropesis in the aliphatic series argues most strongly for the same sort of oscillation in the aromatic series wherever circumstances are favorable for its existence. In fact it seems highly probable that its presence alone will account for all the color-formations in the aromatic series. Other vibratory centers may exist and in fact do exist in the various compounds, but their presence only influences the amount of isorropesis that can take place and does not altogether destroy this particular form of oscillation.

In the quinoïd type of compounds the actual existence of the two distinct modifications which underlie isorropesis has already been shown. The change of one of these forms into the other and *vice versa* necessitates a change in manner of linking throughout the molecule which accompanies the oscillation in question. The fact that no one arrangement of atoms, no matter what their method of linking, can be made to show an absorption band is sufficient in itself to argue for the make-and-break in the two forms of the quinone as the cause of the color that exists among members of this class. For many years the quinoïd linking has been supposed to be the source of color in compounds of quinone formation. It was not until recently, however, that Gomberg has been able to prove conclusively that the quinoïd type of linking actually exists in colored compounds of this nature. Not alone the presence of the quinoïd type, but also the benzoïd type has been shown to be present. In fact he has been able to interpret the conditions which determine the equilibrium always existent between these two forms and thus has succeeded in establishing by purely chemical means the amount of quinoïd formation and consequently of isorropesis possible among aromatic derivatives. The spectroscopic evidence, therefore, on the existence of just such a type of oscillation as may be present in equilibria of this nature is corroborated. Upon the amount of isorropesis shown—a factor always dependent upon the relative unsaturated condition of the atoms coming into juxtaposition—we arrive at the depth of color in any given equilibrium. The presence of other groups may augment or retard the influence of these unsaturated atoms undergoing isorropesis, and consequently the corresponding variations in the oscillation frequency will be indicated by similar variation in the nature of the color. In many ring compounds where no such arrangement of linkings, as in the benzoïd and quinoïd classes, is seen, almost no evidence of color can be found. Furfuran, pyrol, camphor and many others of a constitution exhibiting double linkings show only general absorption in their spectra. But whenever the benzoïd type is present, no matter whether the ring be composed entirely of carbon atoms or not, the conditions for isorropesis are at once favored so soon as unsaturated atoms or groups can be introduced. These groups by their unsaturated condition give rise to new linkings and then in turn undergo the make-and-break characteristic of substances showing selective absorption.

Indeed we come to the conclusion that isorropesis is the cause of color in the aromatic series as well as in the aliphatic series. In both series the two modifications which must always be *in statu nascendi* have actually been shown to exist. The change of linking, therefore, that must accompany the transformation of one into the other is certainly to be considered as the source of the oscillations which give rise to vibrations in the ether of a free period corresponding to those in the visible region of the spectrum, and hence the development of color in the substance. The application of these ideas to the interpretation of color among inorganic compounds is yet to be made. There seems, however, no doubt but that, where residual affinity exists, there may arise some form of oscillation, caused by the make-and-break of these induced linkings as brought about by the molecular movements, which will record itself in definite vibratory motions of the ether and consequently, if these vibrations are of low enough frequency, will indicate color in the compound. Not until something of a more definite nature is known as regards the true spatial arrangement of the atoms in these compounds, can anything of positive value be postulated concerning the disturbances which certain atoms may bring to bear upon other atoms or groups of atoms in the molecule. Consequently the periods of oscillation that correspond to many of our well known colored salts have received no explanation in terms of those periods so definitely established among the carbon compounds; periods which through spectroscopic evidence have been made to reveal so much concerning the internal vibrations of the atoms in the molecule and of the disturbances within the atoms themselves.

GERMAN INFLUENCE IN LATIN AMERICA

By ALFRED F. SEARS, C. E.

PORTLAND, ORE.

I. *Magnitude and Character of German Immigration*

IN 1901 the American citizen was startled by the information from Rio Janeiro, that "A German syndicate has just been formed with a capital of 25,000,000 Marks, with the object of colonizing in Brazil, the states of Rio Grande do Sul, São Paulo, Santa Catarina, Paraná, Minas Garaes and Goyas. The government has guaranteed 5 per cent. interest on the investment in the enterprise."

At about the same time a further statement was published to the effect that the powers of Europe are combining to overthrow our formidable Monroe doctrine, through a society recently organized in Rome for colonization by Italians in various sections of Brazil.

American newspapers declared "the German problem in South America to have been brought sharply to the attention of the national administration by this despatch" made the subject of editorials more or less intelligent all over the land. Some of the newspapers were sufficiently sane to offer their readers definite figures on which to base judgment of American duty. Generally, the patriotic bias developed but little jingoism in the complacent American press. Washington, from the heart of things, assured the nation that Germany is our firm friend, innocent of all design against the bogie we have raised on our neighbors' towers.

While the passion of suspicion concerning the Kaiser's intention was yet alive, the writer was in South America to execute a scientific commission. He had previously spent sixteen years of active professional life in Mexico, Central and South America and believed that he could serve the interests of his country and the impulse of an improved civilization by presenting data for the intelligent consideration of questions involved in foreign colonization schemes among our southern neighbors and illustrating the results to be reached by Teutonic influence among the elements of Latin American life, now so grossly amalgamated with aboriginal barbarism, the slave and tool of Spanish medieval ecclesiasticism, which breeds and fosters social and political immorality.

With this end in view, he addressed a circular to official representatives of all the republics in these continents, soliciting a statement of:

1. How many Germans are settled in the states represented by the officer addressed?

2. Are they settled in collected colonies or scattered over the country?

3. Are they generally engaged in agriculture or in other pursuits?

With this circular a blank form for reply was enclosed, covering all necessary ground for securing a comprehensive description of the condition of German colonization in Latin America.

A general cordiality was encountered among members of the diplomatic and consular services in giving the information at their command, so that reports, more or less definite, were received from every one of the republics. They are here presented in tabular form to aid in a study that shall reach a fair understanding of one of the most important problems facing the American people; one that will appear the crucial problem of the twentieth century. It concerns the enfranchisement of 60,000,000 human beings, the inhabitants of this western hemisphere, and their consequent entry into a superior civilization.

The tabulation proceeds from Mexico, our nearest neighbor, to the most remote state of the southern continent, preserving thus a correct spectrum of the geographical relations.

These figures will be a revelation to the alarmist, apprehensive that Latin America is being submerged beneath a German population

Names of Republics.	Area in Square Miles.	Total Population.	No. of Germans.
Mexico	800,000	14,000,000	2,000
Guatemala	47,000	1,600,000	6,000
Honduras	43,000	420,000	50
Salvador	7,000	1,000,000	1,000
Nicaragua	52,000	420,000	600
Costa Rica	20,000	310,000	340
Colombia	331,000	5,000,000	150
Venezuela	566,666	2,500,000	3,000
Brazil	3,200,000	18,000,000	1,000,000
Ecuador	144,000	1,500,000	300
Peru	405,000	4,000,000	3,000
Bolivia	472,000	2,500,000	400
Uruguay	72,000	1,000,000	765
Paraguay	145,000	600,000	916
Chile	257,000	3,000,000	15,000
Argentina	3,100.000	5,000,000	17,143

devoted to monarchism. We find 1,051,000 Germans spread over an area of 8,000,000 square miles of territory, already occupied by a native population of more than 60,000,000, who have secured through war their independence of foreign domination, which they show a disposition to guard with jealous watchfulness.

In the comments appended to their reports by consuls and ministers there is the unanimous agreement that German immigrants constitute a most desirable class of citizens. The reader will observe that the mass of German immigration has settled in the temperate zones of the continent, avoiding the tropics. Thus we find 32,000 or more are colonized in Chile and Argentina, regions extending as far south as forty degrees from the equator, while the Brazilian colonies of São Paulo, Paraná and Rio Grande do Sul are in the south of the republic, extending to thirty-five degrees below the equator and containing the mass of the German population, though there are some thousands in the tropical state of Minas Geraes lying between fourteen and twenty-three degrees south of the equator, a mountain mining region, where altitude supersedes latitude in the comfort of temperature.

There is no considerable condensation of Germans in colonies, save in Brazil, Chile and Argentina, there being but 20,000 of them distributed among the other thirteen states of the continent. These people are generally engaged in commerce and trade. In the commercial cities the jewelry business and that of money exchange are almost universally conducted by Germans, generally Jews, who, when not so engaged, are devoted to some other branch of city retail trade. The subjects of this religious faith are excellent citizens and are always appealed to for assistance in public charities; they are more popular as municipal officers than pronounced protestant christians of any nationality. Leading commercial houses in all the republics have German branches operated by young men sent out from the mother country to conduct the American end of their business. It is quite the rule for these men to marry in the country, nor do they condescend to the inferior classes. Their positions are guarantees of character, so that they have access to the best families, differing in this from the English and Americans, who rarely marry with people of the Latin republics.

The blue eyes, fair hair, clear complexions and general bonhomie of the Germans make them singularly attractive companions to the merry, black-eyed brunette of our southern neighbors. By his wonderful adaptation to the national customs and popular convention, with his extraordinary ability in the mastery of language foreign to his native tongue, his absolute grammatical accuracy in construction with correct pronunciation, he becomes an accomplished member of society, a valuable citizen, a desirable neighbor and an agreeable companion; while the American, like the Englishman, always aggressive, often offensively so, rarely attains a command of the language superior to a "gringo" idiom and contemptuously mentions the people among whom he lives as "the natives," implying their slight remove in his conception from the aboriginees.

But the Englishman is better regarded than the average American, because he goes among the people as the contracted agent or clerk of a reputable commercial house, while the American is rarely other than accident or an adventurer. In no case are either of these immigrants such representatives or instruments of an advanced civilization as their countrymen at home may properly imagine them. At their best, they are the simple agents of commercialism; and in Latin America, as at home, they leave their neighbors to that liberty in their pursuits, opinions, methods and manners which they claim and exercise for themselves.

To Brazil, as to Chile and to Argentina, have been presented lower classes of Germans, who have taken to agriculture and have grouped themselves in colonies, from which some of the more intelligent have escaped to the towns and cities, where they have entered the pursuits of the mechanic arts or trade.

The European economist, quoted by the American Bureau of Statistics, estimates that "German capitalists have invested $50,000,000 in Mexico and $225,000,000 in South America, of which $150,000,000 are in Brazil alone, in the southern provinces of which several great German colonization societies have long had powerful influence. Land may be bought there at half the price of government lands in the United States, and land that produces several crops a year in agreeable, healthy climates."

As shown by the figures, while only 51,000 Germans are settled among the states of the continent, outside of Brazil, the 1,000,000 in that country are colonized in five states.

In Paraná, with	80,000	inhabitants, covering	6,000	square miles.
Santa Catarina, with	110,000	inhabitants, covering	24,000	square miles.
Rio Grande do Sul, with	300,000	inhabitants, covering	99,000	square miles.
São Paulo, with	540,000	inhabitants, covering	121,000	square miles.
Minas Garaes, with	1,300,000	inhabitants, covering	220,000	square miles.

These states with 2,330,000 inhabitants living over an area of 470,000 square miles contain 1,000,000 Germans, living among a people of whom only one sixth are whites of self-governing ability. Generally these immigrants are farmers, save, as already mentioned, laborers, who have been sent to the mining regions of Minas Garaes by the home colonization companies for work in the mines and the production of supplies for the mining operations.

It may also be noted that Central America is a favorite point for the German leaving home. But it should be said here that few, if not the more wealthy and cultivated among them, go to those states, where they are having a very important influence on commerce, the arts and every department of civilization. So important have these interests become that the German government has lately established there its first salaried consulate, where also are about a score of consular agents receiving their pay in fees. Their commercial interests, especially in Guatemala, have so developed that they have now in the five little republics $6,000,000 invested in real estate, industrial enterprises and banking business. German farms and plantations cover more than 742,000 acres, on which are 20,000,000 coffee trees, while the trade between those states and Germany amounts to $12,000,000 a year. Throughout Central America, Germans occupy leading positions in business management, professional and social life.

II. *Condition of the Societies invaded by German Immigration*

We have passed the portals and come into the glory of a new century of this modern era. The genius of man, which has reared our present civilization through more than four centuries of patient culture, struggling to free himself from the divine right of priest and king forced upon his mind by superstitious fear of a tyrannical and mercenary ecclesiasticism, has at last invaded the highways of the heavens, followed the journeyings of other worlds and, driving away the guard, has seized the tables of their law, so long falsified by "sacred" authority, and brought them to earth for the common use of the race; has plunged into the heart of his own planet and, seeking the smelteries of the gods, brought forth their ores of light and power, illuminating the world and confounding the agents of "inspiration" by exposing the sources of creation.

By the omnipotence of carbon with the industry of the printing press, the world has been condensed and its nations drawn into the circle of neighborhood sympathics, with the elevating and degrading influences of the world's gossip; its gabble and wisdom, truth and falsehood, loving tenderness and brutal antagonism, so assorted, allotted and mingled, the nations are becoming one people. The political monarch is being forced to concede parliaments to thought, which dares deride royal pretensions, wherefore this century seems likely to witness the downfall of all enthroned power save that of the people. The last tyrant to fall, because the most difficult to reach, being ambushed in the superstitious apprehension of the masses, will be the religio-political governments of Latin America; governments that are not in any sense democratic republics, though so titled in their constitutions and proclaimed in their manifestoes. Comprehensively described, they are autocratic theocracies, in which the common people are under the dominion of the clergy, who, in their turn, are the instruments of the educated wealthy classes, holding control of the administration of the governments; or, when the laws are not to their purpose, organizing revolution to overturn their rivals of the party in power when they reckon themselves sufficiently strong in the reenforcing influence of the church.

There is, however, in every Latin state a party of which the grand objective is the religious and civil freedom to be obtained by the separation of church and state. This party recognizes the value of a public school system, like that of the United States, molding the popular mind to the habit and method of independent thought. In the parochial schools of the present, where the children have their first and, generally, their only training, the object appears to be the drilling into the young mind supreme reverence for the power of the clergy to inflict future punishment and bestow reward, with the church as an object of veneration in place of Deity.

The Roman pontiff is now without influence in appointing the archbishops, or superior clergy, in any Latin republic. The supreme political power of the state nominates the candidate because of his political relation to the party in power, and he is confirmed by the pope without question. By this method only can Rome maintain the slim hold it now possesses on a people, of whom the educated classes, clergy and laity alike, are agnostic when they are not absolutely atheistic. Their church is simply an institution of society, which confers a child's name with ceremonious dignity, marries him with the customary, established form and receives his dying breath in such compliance with ecclesiastical demand as shall secure for the corpse a burial in consecrated ground, which means a "respectable" interment.

So universally detestable is the popular reputation of the Latin American priest that in the more civilized cities of their realm they are not admitted to social life in the upper circles of society by self-respecting husbands and fathers of young wives and daughters. A result of this moral debasement in the font of ethical teaching is the general dull public conscience concerning all obligations, social, political and economic, that we actually find in existence throughout Latin America. It is seen in the smallest business transactions and the most important financial contracts. A South American bond without hypothecated security is a broad jest in all financial centers.

The aboriginal population of those regions are not civilized, but have been christianized through a system of oppression that has endured five centuries. Sarcastically entitled "citizens," they are without a voice in government, and when their tribal center is far removed from the larger cities, they are in a more repulsive condition of barbarism than when the cross was first raised over them.

When Pizarro subjugated the gentle subjects of the Incas, Perú had a population of 12,000,000 industrious, virtuous and contented souls, since reduced by Spanish slavery to less than 3,000,000; to-day, after a half century of recuperative government, raised to nearly 4,000,000, the systems of their christian conquerors having slain 9,000,000 in the mines by the meta, which kept one seventh of the population always at work for their masters, the Spaniards. Cannibals still roam in the territories about the head waters of the Amazon. In Mexico are districts where the women know no other dress than a piece of cotton dropping from the waist to the knee; and the Jesuits have controlled them during all these centuries, superstitious devotees of the church, without a conception of modesty or chastity as recognized by our civilization. Reports of prefects of departments and governors of states annually present records of an unwholesome condition of public morality, often indicated by the exorbitant proportion of illegitimate births in a population generally amounting throughout Latin America to from 25 to 40 per cent. of the entire number in a republic.

At a meeting of the American Social Science Association, held in Washington in April, 1901, Ex-Secretary John W. Foster said of the Latin American republics: "The great mass of their populations are ignorant and uneducated; in many of the countries they do not even read and write the official language of their governments, and as a rule have no part in the elections." It has been claimed for the Spanish missionaries that they taught the Mexicans all over that country the Spanish language. Nothing can be farther from the truth. In a population of 14,000,000 not more than 4,000,000 speak the language of the government. When the railroad companies have had to employ laborers from the Sierras, they have been obliged to bring with each gang an interpreter who speaks the dialect of the tribe and Spanish, which the native does not understand.

These details are mentioned, not to prove, but to illustrate, a condition known beyond the necessity for proof by every intelligent citizen of the world. Every soldier from the Spanish islands learned the fact by personal contact; travelers from all over christendom who have visited those regions know the truth and entertain their friends with the recital. The thousands of Spanish prisoners to American arms in Cuba, transported to their homes, are become missionaries against the tyranny of their native church. All over Spain they have proceeded with violence against an institution that contact with the free thought of America has taught them to hate as the enemy of human rights; the auxiliary of tyrants "clad in the livery of heaven."

This corrupt ecclesiastical system, still striving to hold in subversion the consciences of 60,000,000 human souls in this western continent, is tottering in its power under the contempt of the educated classes, its tyrannical masters and the hatred of the common people, with the progressive intelligence of the popular conscience, to which the clergy is being continually forced to make unwilling concessions. It is also to be observed that contact with the Saxon world is stimulating the Latin factor of it to shake off the yoke of that ecclesiasticism which has debauched and, in every moral, intellectual and spiritual sense, degraded the masses to be the scum of the world's populations. At last, the head of the Latin church has aroused to the alarming fact of a great western awakening. Associated press despatches tell us that on June 28, 1903, the pope called the bishop of Ibague (Colombia) to an audience, in which he is reported to have conversed on conditions prevailing in the South American republics and the "necessity of raising the standard of the clergy so that they may contribute to the better intellectual and moral condition and progress of the people of those countries." The clerical apprehension of approaching danger is shown in various attempts to hide or destroy ancient insignia of idolatrous superstition; thus, witness on the façade of the church of La Merced in Lima, the capital of Perú, there existed up to a few years ago the following inscription upon a fillet over the grand portal, "Indulgencia, plenaria, cuotidiana, perpetua por los vivos y los difuntos." It has now been removed under the sneers of an advancing civilization of the people and the sensitiveness of all to the comment of foreigners.

This is but a single instance among many illustrating the trend of a growing influence among the people, obliging the clergy to abandon its methods and pretensions. A half century ago, the priest in blessing the national troops in Costa Rica walked over the abased national flag to sprinkle it and the troops with holy water. To-day the flag is laid reverently upon a table and the priest walks around it in the performance of the ceremony.

Probably the story of the priest, Francisco Pablo De Vigil D.D., of Lima, is the most comprehensive illustration of the condition of life in its relation to the features here treated that can be presented in one single biography. This distinguished theologian, scholar and statesman was excommunicated from his church because he refused to accept the dogma of papal infallibility. Notwithstanding his expulsion, he continued to wear the ecclesiastical garb and the tonsure and to attend the functions of the church, occupying a seat among the laity. He had warm friends and sympathizers among the lower clergy, but could not receive absolution after confession, since he refused to renounce his error. The national government, recognizing his purity of character, his high degree of scholarship and devotion to liberty of thought, placed him in charge of the national museum, which is a great educational institution of Lima, and brought him into close intellectual contact with the students of the university, so that in this position he had the largest field he had ever yet possessed for influencing the growing mind of the nation. While occupying this station, he died. His death and funeral were as full of interest in the world of thought as his life had been. A personal friend in the priesthood attended him in the last hour and received his confession, but had been expressly forbidden to give him absolution, unless he renounced his error. His confessor relates that he was weeping as he knelt by the bedside of his dying friend, who laid his hand tenderly upon his head and said, "Don't weep for me, dear brother, but for the archbishop, whom you but obey; I am going before a greater judge than he." The body was refused admission to the church of La Merced for the ordinary requiem mass, and the clergy also refused the certificate required for burial in the

"Pantheon general," which, while "consecrated," is the property of the municipality. This body immediately, by municipal ordinance, authorized the interment of the body of Dr. Vigil within its consecrated grounds. When the body was brought from the house to be laid in the hearse awaiting its reception, a body of students stepped forward and took it upon their shoulders, bearing it reverently to the chapel of the cemetery.

But now, another surprise awaited the wondering public. As the funeral cortège moved along the streets of the city, processions of Free Masons in full regalia poured from the side streets and followed the train. On reaching the chapel, Masons took charge and conducted the burial service, in the name of human liberty; and in the chapel, which had been consecrated by the church, but was owned by the municipality. The same order conducted the ceremonies at the grave, with the solemn earnestness of men, who understood the act to be a declaration of independence against ecclesiastical tyranny. The higher clergy beheld the spectacle with fear and indignation, while the priests smiled solemnly to see their bishop defied in his own capital. None of them had dreamed that a masonic lodge existed in their midst; to-day the handsomest, best built and most modern structure in the commercial city of Callao is the Masonic temple.

Since then the city of Tacna, capital of a southern department of Perú, has erected a fine marble monument to the memory of Dr. Pablo Francisco De Vigil, who was a native son of that town.

This entire episode, in its defiance of the clergy, illustrates the longing for liberty in the better classes of Latin America. But, in all these republics, there is more actual liberty of conscience than is allowed by the written law, which, often angrily cited by the clergy, finds itself in such antagonism to the higher law of the popular conscience, that the courts of ultimate authority manage to fail of finding it in the statute books, written as it is under the unwritten decrees of an advancing civilization.

III. *German Influence in Latin America*

It is an interesting fact that in all the vigorous eloquence of the American press and politician, touching "German influence" in these continents, the real matter of German influence has not once been considered. European monarchism, interpreted by the Kaiser, has excited the patriotic bias of the republican citizen, as if the ambition of Cæsarism can ever establish its order among a people who have fought for and conquered their independence. German imperial power must not be confounded with German influence, which has been potent on this continent for more than a half century and will continue to be as long as Germany occupies her present transcendent position in the universe of thought.

It is not to be disputed that the German business man, whether in commerce or in the industrial professions, assumes always in Latin America a positive antagonism to the American from these states, often violent and offensive. This action is partly the exhibition of his inflated vanity and partly proceeds from his spirit of business rivalry.

Dr. Herman Meyer, a founder of a German colony in southern Brazil, in an address before the Berlin Colonial Society, said, in December, 1904, that United States merchants are trying to win the trade of the German settlers in Brazil and that therefore it will be necessary to assist the colonies with German capital for the purpose of building railroads and creating industrial establishments.

The pronounced opinion of Dr. Vosberg-Rekow, director of the Bureau of Commercial Treaties, before a meeting of Leipzig merchants, that "Germany must have annexation of more territory beyond the sea, with the organization and the direction of emigration thereto"; the warning of the Italian admiral, Count Canevare, that "European nations may have to consider the necessity of uniting against America," with the concurrent expression of Count Goluchowski, the Austrian minister of foreign affairs, are not agreeable trumpetings across the seas, but they bear no relation to the power or character of the German influence at present existing in these western continents.

A positive and powerful German influence, the grand ally of the Americanism of free opinion with its expression, is exercised in all countries settled by German immigration; it is radically liberal in religion and politics, without the element of anarchism; antimonarchistic and altogether contemptuous of conditions existing in the countries of its adoption.

This statement requires qualification when treating of the larger "assisted" colonies which contain inferior classes of population. Thus in Brazil a considerable proportion of the German immigration is of peasantry of Baden-Baden, whose people, the last to be joined in the German confederacy, came into the empire through conquest. The ruling power of the principality is protestant in religion, while two thirds of the population is Romanistic, and furnishes the element which is peopling the southern states of Brazil. They are, in the main, a thick-headed, patient, industrious race, repaying the Prussian contempt with sincerely cordial hatred. They find in Brazil a mentally stimulating life, an emancipation from protestant though liberal rule, allowing them an assumption of superiority over the natives of the new country. Their priests are men of character, superior to the native clergy in every element of intellectual, moral and spiritual life, while they possess a fair degree of learning and are devoted pastors. But these German peasants of Brazil are superstitious and illiterate when compared with the Germans, scattered over the continent as merchants, clerks, brokers, bankers, planters and teachers. Their influence on the natives of the region where they live is but trifling, save in the particular of their superior morality, which is believed to be an elevating example, while, like all Germans, everywhere, they grow in their new soil towards liberal thought, being removed from the repressive influence of European old age. They are not in any sense subjects of German imperial power, but are the tenants of commercial companies. So that, while they are German colonists, they are not colonies of Germany.

If the material results thus far accomplished by the German government in its attempts at national colonization be the best that power is able to produce, it will appear an empty vanity to attempt further enterprises of the kind, save for the improvement of congested populations. In colonies of the empire, covering an area of 2,500,000 square miles there is a white population of 6,000 souls, of whom 4,000 are Germans, who in one year (1901) succeeded in producing a deficit of $7,000,000 above an income of $8,000,000. American Consul Harris at Eibenstock has said: "The ideal relation of a colony to the mother country is that which permits the colony to produce the raw material which the mother country will receive and return to the colony in a manufactured condition; but, in accordance with an irresistible law of economics, a colony with great material resources will gradually emancipate itself from the mother country. It is doubtful whether this will shortly be true of any of the present colonies of Germany. In almost every part of the world where her acquisitions are situated, there is in the same immediate neighorhood a colony of Great Britain or some other country better able to produce colonial products."

The only considerable collected German colonies, in other of the Latin American republics, are in Guatemala, Chile and Argentina. In Guatemala there is a German element of great respectability and influence amounting to real power, which promises more for an advancing civilization of the entire mass of population than is apparent in Chile or Argentina. But, in all three of these republics are German populations, not included in colonies, which must be considered with similar classes in every other Latin American state. These people are distributed all through those states, but are found more generally in the large towns and cities. They represent important material interests and are the potent "leaven which leaveneth the whole lump."

The influence of this portion on the communities in which they live differs curiously from that of the French, as is seen illustrated in the cities of Mexico and Panama, where the French have, during certain periods, been the controlling power in social life. The women of the upper classes of those cities, which have known French influence, no longer hesitate to appear on the streets clad in comely array, wearing bright colors in dress, with hats or bonnets in place of the sombre black suit of gown and mantilla. Thirty years ago, every woman in the

Panama cathedral was arrayed in black and even her head was covered with a black manta; there being no pews, she knelt on the stone floor throughout the service. Since the French began the work of the canal, the church has been supplied with pews and the women are wearing in the services the hats and bonnets of Parisian fashion with gowns and wraps à la mode.

German influence, on the contrary, so far as I have discovered, seems not to have affected the fashions of dress or social customs of the people, but is revolutionary to an extraordinary degree in its effect on the mental attitude towards the elements of civilization in politics and religion and the education of the youth. Many native fathers send their sons to Heidelberg, rather than to Freiburg, the school of their faith, though generally scientific students begin their studies at the technical institutions of the United States and finish them with two years at the Polytechnic School of Paris.

Notwithstanding the fact that German antagonism to mental and spiritual tyranny is awaking the popular sense to freedom, the molding of social conditions and the philosophic thought are distinctly French. The truth is the Latin spirit is French rather than German, so that Paris and not Berlin is shaping the social life of Latin America. The civilized world regards in wonder the spectacle of 60,000,000 people, who have thrown off the yoke of Spain, suffering in sullen silence the tyrannical imposition of an institution more strictly Spanish than any political monarchism they had ever known.

But the church in Latin America is to-day brought face to face with an army of organized thought, invulnerable to the senile bulls of ecclesiasticism. As Victor Emanuel was able in the interest of Italian unity to discuss the forbidden questions of the usurpation of civil power, in the privacy of the Masonic Lodge with his brother princes of Italy, so masonry is to-day, throughout Latin America, the safe and sacred cradle of liberty, an important instrument aiding to emancipate the state from priestly tyranny.

Masonry is making great strides in all the republics since the establishment of the new kingdom of Italy, which has been a lesson in method to the advocates of liberty of opinion, who have learned its value in freeing them from the espionage of those who mold and bind the shackles of thought. Its adherents are everywhere the advocates of the separation of church and state. Visible progress towards this desirable end is slow, but as sure as the irresistible march of time.

In this developing menace, the German has been the grandly potent factor throughout those regions. Everywhere he is the active leader in freedom of thought and in the conduct of masonic lodges. As it is not permitted to teach protestantism, a German, the grand master of the Peruvian orient, has established a newspaper in Lima, the capital city of Perú, which he calls the *Libre Pensador,* which is doing effective work for freedom of conscience and secular education of the children; for which, in many of the republics, the city councils have established "municipal schools." The course of the *Libre Pensador* is supported by the higher classes of the community as a veritable watchman on the tower of free expression, and is doing much to relieve society of clerical scandals, which it trumpets with terrible denunciation and directness of personality.

The extraordinary material development of territories rescued from their Mexican slavery under clericalism and raised into the dignity of our American statehood, allowing them all their natural advantages for development, is an index of what the world may witness in the redemption of other Latin American republics. The advance in every higher condition of life in the Republic of Mexico, since her partial emancipation from this same wretched rule, affords a great encouragement to the moralist, philosopher and statesman, watching the progress of the world in the march of free popular thought, applied to the government of states.

The writer is an American, with three hundred years of unmixed American ancestry behind him, and he does not hesitate to declare his belief, after having lived nearly a score of years in Mexico, Central and South America, that if it should be the fortune of any considerable territory of South America to rise into the dominion of English, French or German civilization, it would denote a triumph of regenerating thought over a condition of slavery that should never have been permitted to establish a foothold in these continents. It would mean republican states that we could respect as neighbors, our equals and our coadjutors in advancing the conditions of liberty throughout the western world, instead of protegés, whose frequent acts of barbarism keep our country in constant apprehension of Monrovian interference that may embroil the nation in a war with the states of Europe. And for what? to sustain a people in maintaining republics? Nothing of the kind; but to save some miserable band of politicians from the punishment due their crimes against the illuminating ideas of this twentieth century, fruit of the highest civilization.

THE PROBLEM OF INTERNATIONAL SPEECH

BY ANNA MONSCH ROBERTS

MANHATTAN, KANS.

TO any thoughtful student of affairs, it is perfectly clear that, as the years go by, all the nations of the earth must inevitably become more and more closely linked together in all their interests. The present highly perfected modes of communication will become greatly improved and vastly extended. All the economic and material commercial, as well as all the intellectual interests of each people will become of increasing significance to every other one. National boundaries will, in the lapse of time, become of as purely formal, merely administrative importance as are our American state and county boundaries to-day. Already in The Hague tribunal we have the beginnings of an international supreme court. In time the United States of Europe is a conceivable possibility, with abolished frontiers and armies reduced to police forces. Commerce and industry are certain to end the folly and barbarism of war; since the rise to self-consciousness of the working classes (who fill the armies) will make their community of interest the world over plain to themselves, and they will see that to hire themselves out to kill one another is a crime to common humanity.

One prime obstacle to that clear and perfect understanding among human minds everywhere over the broad earth lies in their inability fully to comprehend one another's thoughts and purposes, because of the diversity of tongues. That this is a very serious obstacle to human progress and the development of the globe, becomes increasingly evident the more readily and easily possible communication by mail, telegraph and actual travel becomes. So long as the different peoples read little, wrote less, and traveled scarcely at all, the polyglot condition of the world was a matter of little interest. To-day it has risen to be a most serious hindrance and inconvenience to the steps of advancing humanity. It is true that almost all educated persons feel impelled to-day to attempt the learning of other languages than their own, if only to come in touch with the civilized world's literature, aside from the ordinary practical considerations. Sometimes this feeling petrifies into the pious attitude ironically commended by Lord Palmerston, who said that while it was not necessary that every gentleman should *know* Latin, he should at least have *forgotten* it.

It is trite and easy to say that this is a scientific age, but one must actually have worked in some field of science to realize the blundering, clumsy stupidity of the present language situation. A good half dozen languages at least, must become the working tools of him who conducts scientific research of any importance; for men all over the civilized globe are carrying on investigations in all the departments of science, and their results are being published in hundreds of scientific journals in many tongues. To be sure, reviewers having special acquaintance with the less known languages translate many of these investigations—or, at least, more or less imperfectly report their main features in the journals of science published in German, French, Italian and English, which all scientific men are supposed to read. It goes without saying, however, that hundreds of valuable papers are buried each year in the minor languages and dialects, while even in the four great European tongues much of importance is overlooked by reviewers in the others. The situation is even worse when an international congress is convened. Such meetings are being held with increasing frequency—twenty-two in Geneva, Switzerland, last summer—to consider all topics of common human interest : Medicine, prison reform, agriculture, peace, the Red Cross, sanitation, education, besides the special societies for all the great branches of science. At present it is the universal rule that at all such gatherings papers may be read and discussions conducted in any one of the four languages above mentioned. There are always some, often many, who can understand formal papers, if read very slowly, fairly well in at least two of these idioms. But to converse freely, easily and continuously with others upon all topics of common interest in another than one's own native tongue is a feat more often imagined than realized.

In view of the amazing progress we are daily achieving in all the other departments of human life, why, with respect to the one indispensable tool of language, should the human race suffer no improvement? Why not agree upon one auxiliary common language, which all people of moderate education may easily learn. Why must the Magyar or the Slav, the Chinese or the Japanese, of culture and intelligence, be barred by language from the tremendous world of thought in the intellectual life-centers of the globe? In the to-morrow that is coming, shall we exclude ourselves from Russian, Chinese or Japanese life and thought, as much as they to-day are excluded from ours, except at the expense of laborious language-learning. But consider for a moment the situation confronting, let us say, a cultivated Japanese desirous of entering European thought. First, Greek and Latin ought to be acquired, and English, French and German absolutely *must* be mastered, every one of them absolutely alien to his own tongue in grammar and vocabulary, and even in the very written signs themselves.

It is one thing to engage in the study of foreign languages with love in one's heart for the beauty of their literatures; it is quite another, and a different thing, to endure years of joyless toil, acquiring a smattering of many tongues in order to gain a mere technical ability to read the facts of science internationally. What wanton brain-waste is here. Scientific investigation and discovery are of no nation, of no language, but to be in possession of the knowledge of them, in the present crude stage of our social development, we must learn a half-score of the national languages in a way that is subversive to all mental discipline, to all culture. Either we are skated over the thin ice of a "conversational course," getting our vocabulary with our breath between glides, and with grammar served daintily, like Nabisco wafers at a luncheon. Or we have had, let us say, the good average representative "language course" in school and college. We have "pried over" from one language into another endless imbecile sentences, involving the fact that Marie, when she shall have had a lead pencil will have been happy; that Henry's uncle, who is about to return from Frankfurt, desires an inkstand for his little sister; or concerning the ravages committed by the red cow of the good grandmother in the green garden of the rich count. We have read a half dozen plays; have rendered slowly, dully, baldly, into "translation English," a few hundred pages, more or less, of standard prose and verse—and we have "had" French, we have "had" German. How many of us must testify to the inadequacy of the average "required" courses in language to give appreciation for foreign literatures, while of course their utter inefficiency, so far as the direct conversational use of these tongues is concerned, must be self-evident, in view of the laughter-provoking absurdities in style and diction, the impossible pronunciations and accents we achieve.

In one of George du Maurier's books, two little English boys in a French school are requested by the master, proud of his own English, to render into its English equivalent, "je voudrais pouvoir." Translated "I should like to be able" by the little Englishmen, they were at once corrected by the master. "Non, non, you do not know your native tongue. It is to say, '*I vould vill to can*'" Being then told to translate, "*je pourrais vouloir*," from the small bad boys came the alert response, "*I vould can to vill.*"

We all know, from both literature and life, the appalling waste, the tremendous throwing about of brains to little use, in much of the current study of foreign languages.

Recognizing the difficulties involved in learning the natural tongues, the minds of men have been occupied for more than two hundred years with projects for an artificial language that should be the means for international communication. But the thought naturally suggests itself—why should we not make use for this purpose, of some one of the already existing idioms, developing and simplifying it if necessary. Logically the great classical tongues of Greek and Latin come in first for consideration. It has been demonstrated, however, that for many reasons they are impossible. Their highly inflected structure, their inverted sentence order, especially in the case of the Latin, are wholly alien to the modern mind. For centuries, indeed, Latin retained a certain sort of internationality among scholars and churchmen, but not in the common walks of life; while Greek, in spite of the four millions of modern Greeks, could make no propaganda, because, in addition to countless inflections, it retains an unfamiliar alphabet.

Considering the four principal modern languages, French, English, German and Italian, the first two alone have ever been able to entertain even a hope of becoming international. Among diplomats, courtiers, officials and people of polish and culture generally, French has of course for many centuries been regarded as an indispensable tongue, and in this way it has actually attained to a limited amount of internationality. The precision, neatness and certain high quality of style in its phrase, its rather simple grammar and its capacity for expressing nice distinctions and fine shades of meaning, must always strongly appeal in its favor. Its difficulties of idiom, and particularly its pronunciation and accent, which absolutely can not be correctly acquired by adults, and which can be conveyed only by the cultivated French teachers themselves to ourselves as children, preclude all hope for the universality of French in any but an academic sense.

Germany, the Mecca of scientists, publishes every year an absolutely appalling mass of scientific literature; so that to every investigator, a reading knowledge at least, of German, is as indispensable as his native tongue, whatever that may happen to be. Yet German, cumbered with a clumsy, inverted sentence-order, with its complex inflections of nouns and verbs, its incredible genders and its rather difficult pronunciation, has never dared even to aspire to internationality. Except that the Germans are indefatigable workers, and publish an inconceivable volume of scientific literature, their tongue would to-day be no more widely known than Danish.

As to our own well-beloved mother tongue, we are told on every hand (in English-speaking countries) that English is rapidly becoming the world-language. We are confronted with census statistics to this point; but an analysis of the figures somewhat weakens the force of the general assertion. In America, and in the English and American dependencies, there are absolute hordes of non-English-speaking peoples. But even were this otherwise, allowing the utmost to the figures, we should still have but a minor part of the inhabitants of the civilized world as users of English.

What are then the inducements to bring the rest of the world to the speaking of English? Who does not remember the story of the valiant

British matron, who, on being accosted in southern France by the phrase, "You foreigners," replied: "No, *you* are '*foreigners*,' *we* are *English*." To your true, insular, middle-class Englishman, all the rest of the world, with patronizing exception of the Americans, is composed of "foreigners," speaking various absurd jargons, wholly impossible to understand, but really quite unimportant after all.

Your American, knowing in his bones that he is a hopeless hash of Irish, German, Scandinavian and Hebrew, with garnishings, perhaps, of "Anglo-Saxon,"—whatever that may be or ever was—is yet no whit less provincial in his noisy assertion of the manifest destiny of the language which he has learned to speak in a way, and with various brogues and accents. To the language slogan of the English, he joins perforce the American Declaration of Independence and the Constitution, both of which are to "follow the flag"—at more or less discreet distance in their more than Roman triumphal progress over the lands of the hitherto unappropriated peoples waiting to be discovered and utilized. If there be such a thing as an Anglo-Saxon idea, upon which England and America are in perfect spiritual accord, it is that all the rest of the unexploited races of the globe should be put at once into Derby hats and trousers, made by the Israelites of London, New York and Chicago, to buy which, satisfactorily and abundantly, the prospective purchasers must, of course, be made to learn "the language of Shakespeare."

The American, who is also an idealist and under illusions, would graft on the suffrage. "Buy our goods, wear our clothes, talk English and vote—for us," is the good orthodox, Anglo-American receipt for civilization.

Suppose, however, we drop national prejudices for awhile, and look at our language through other eyes.

Modern English is, as we know, a magnificent composite, possessing the richest, most varied, most expressive vocabulary imaginable. As fully heir of the polished classical tongues through the Norman French as of the homely and rugged Teutonic stocks through the Saxon, our English language certainly offers us a wealth of words without compare among the civilized tongues of to-day. Add to this a minimum of grammar, an absolute simplicity, flexibility and mobility of structure, and why should English be other than the best possible international form of speech?

What then are the deterrent factors which operate to hinder and check the spread of English? First and foremost, our absurd, impossible and chaotic spelling. To language students, of course, the evolution of our orthography is clearly traceable; but to the plain man of other nations, who has not grown up in English from King Alfred, nothing seems more witless, more grotesque, lawless and incomprehensible than our spelling, and its utter divorce from pronunciation.

We spell *s-l-o-u-g-h,* and call it "sluff" if we refer to an abscess, but "sloo" if we refer to a swamp, over which the wind may be said to *s-o-u-g-h*—"soff." Remove but the initial "s," and we no longer have a swamp, but a lake—*l-o-u-g-h,* pronounced "loch." Change but the "o" to "a," and we have *l-a-u-g-h*—"laff," but *c—a-u-g-h-t*—"cawt," or *dr—a-u-g-h-t*—"draft." Or, again we have *t-o-u-g-h*—"tuff," *b-o-u-g-h*—"bow," *t-h-r-o-u-g-h*—"throo" (but th-*o*-r—o-u-g-h, "thurrow"), *c-o-u-g-h,* "cawff," *d-o-u-g-h,* "doe," and *p-l-o-u-g-h,* "plow."

"*Coughing* in the chill wind *soughing through tough boughs,* which overhang the *sloughy dough*-like *slough* that joins the dismal *lough,* the lonely peasant sat beside his *plough,*" would make good verbal gymnastics for the ambitious foreigner.

The sound of "e-i" is one thing in *freight* and *weight,* and another in *sleight* and *height*; and in "either" it is either *eyther* or *eether,* while to the Irishman it is *naythe*r.

B-o-w is the "bōw" to shoot with, or the "bŏw" of a boat. A man may *glōw* with pride, or *glŏwer* in wrath. We "mōw" the hay, but put it into the "mŏw." We all agree to say "mōon" on the one hand, and "bŏok" on the other (except in England where they say "bōok"), but some of us say "rōot," "rōof" and "hōof," while others say "rŏot," "rŏof" and "hŏof." We all of us put a "fŏot" into a "bōot"" just as surely as we put a "toe" into a "shoe."

Is it any wonder that our English word system seems to a foreigner a museum of unlabeled curiosities?

Our pronunciation and accent, peculiar in themselves, varying, moreover, to distraction over the English-speaking world, are just as serious stumbling-blocks to others, as, say, French and German accent and pronunciation are to us. The six sounds of "a," the four sounds of "e," the two of "i," the five of "o" and the four of "u" give us those delicate assonances, and that fine shading of sound in words that makes for variety, interest and charm; but the complexity with which those twenty-one unmarked vowels invest the correct pronunciation of our English language is absolutely maddening to foreigners, especially since no one can possibly predict from the pronunciation of the vowels in one word their pronunciation in any other word having essentially the same spelling, and no one can possibly say what extraordinarily diverse combinations of vowels and consonants in English may not be pronounced exactly alike.

The very names, moreover, that we give to our vowels, and which are their principal and most frequently recurring sounds in our words, are, with the exception of "o," peculiar to English alone among the European family of languages, as applied to the letters in question. The so-called "continental" sounds of a, e, i, o, u, as in singing do, re, mi, fa, are practically universal, except in the English-speaking countries. Indeed, there seems to be, at least with us in America, a wide-spread sort of shamefacedness about the use of any other but the flat "ā" and "ă" sounds for "a," and the long "e" and "i" sounds for those letters. "Ask," "ȧalf," "wȧft" are pronounced far and wide as "ăsk," "hălf" and "wăft," if not indeed "āysk," "hāyff" and "wāyft." "Amen" is "aye-men," "Alabama," "Kansas," "Iowa" are attractive in their vowels, properly pronounced; but "Ail-bay-ma," "Kain-zuss," "Eyé-o-way" or "Eye-ó-wi" are sufficiently common to indicate the trend among the unchecked multitudes. The Spanish "Colo-rä′-do" is beautiful; but what of our universal "Colo-răd′do," to say nothing of the unspeakable, but, alas, not unheard, "Colo-rāy′-do"? Americans, especially western Americans, do seem to feel it an affectation to use correctly the available sound-materials of the English tongue.

The point is, that while our vowel sounds do admit of beauty and euphony in the spoken tongue, and while our better speakers and more cultivated people do actually use their delicate shadings, to the delight of sensitive ears, the general drift among the English-speaking masses is to limit themselves to the use of a few of the least attractive and melodious of these sounds, and to those which are the least familiar to the masses of other nations as applied to the letters in question. This tendency certainly does not add to the allurements of English for foreigners. So far as the consonants are concerned, we undoubtedly possess one combination, the "th" sound, as in "the," which seems to present unusual difficulties to almost all other peoples. Who can formulate a rule that will cover the irregularities exhibited by "gem" and "get," by "ginger" and "gimlet," by "gill," the measure, and "gill," of fish; of "s" in "serve" and "preserve," "sound" and "resound," "hawsers" and "trousers," that will serve to aid the foreigner learning English?

Taking our orthography as a whole, there seems to be but little hope for the success of any radical scheme for revision. Witness the hoots of derision that, from London to San Francisco, have followed at the heels of Mr. Carnegie and his simple spellers, with their little handful of three hundred phoneticized words. As a matter of fact we are proud of our spelling as a national heritage. It preserves for us "the history of the language." We have a word "phthisical" which we should spell "tizical," since that is its peculiar pronunciation. We refuse to spell it in that way, because the combinations "ph" and "th" have been arbitrarily chosen to represent two Greek letters that do not exist in our alphabet! Despite the weakness of the argument for our orthography as preserving the historical origins of words, it remains as the most potent, because the most sentimental obstacle to reform, unless it be that blind subservience to routine, that love of the unchanged thing for its own sake alone. Be this as it may, our English orthography will gradually, and in time, conform more and more to phonetic principles. But for the practical needs of the non-English, the interest of the language as a world speech, the movement is fairly glacial in its slowness, and the world will not wait.

Our English grammar, while simple in the main, presents some most eccentric irregularities in the conjugation of the verbs and the nouns. Consider some of our amusing singulars and plurals. A dealer, wishing to buy a dozen of that tailor's article called a "goose," after hanging despairingly between "geese" and "gooses" wrote "Send me one tailor's goose. P. S. Send eleven more of the same." We say "mouse" and "mice," but "house" and "houses" (howzes), "blouse" and "blouses" (blowses), while we also say "grouse" and "grouse" alike in singular and plural.

Perhaps our verbs are simple in their use for the most part; but how many of us are absolutely safe on our feet with respect to the use of "may" and "can," of "flee" and "fly," of "shall" and "will," or, dare I say, even of "sit" and "set," or of "lie" and "lay" on occasion? We think we know we *sit* down, that the sun and the hen, *set,* and that we *set* bread. And perhaps we are quite positive as to what we and the sun have done, grammatically speaking, when we have concluded our actions. But after the setting hen has commenced to "set," has she "set," has she "sat," or has she been "seated?" We are as confident that sun "rises" as that it "sets"; and as confident that we "raise" as that we "set" the bread, but how many of us do not vaguely wonder at times, when the process is over, whether that bread has really "risen," or whether it has not "raised" after all?

The conjugation of the verb, that bugbear in all languages, has been reduced to a trifle in English, but we must not forget the distracting irregularities in the past and perfect tenses which our children and uneducated people with logical instinct are constantly endeavoring to straighten out. Why need we say "catch" and "caught," but "snatch" and "snatched," "sing, sang, sung" but "bring, brought, brought"? We say "see, saw, seen," "saw, sawed, sawn." But put the two together into "see-saw," and behold, we say that we have "see-sawed," not that we have "seen-sawn." We have "lit," or we have "lighted" the lamp, but we have "bitten" the apple, even against the authority of the baby, who says "bited." There are those of us who would find it immensely easier to tell whether a man *had been* "drunk," than to know at once, and on the spot, whether the cause of his intoxication were something he "had drunk" or "had drank."

To conclude: the presence of numberless colloquial idioms, impossible to "parse" or to explain by any simple rule, such as render the plays of Shakespeare almost incomprehensible to foreigners, such as throw into despair the students of Aristophanes, these are the characteristic features of every "natural" language, different in each, and no less difficult in the English than elsewhere. While they give a tongue much of its piquancy, its individuality, they immensely augment the difficulties of its mastery.

But, finally, there are two fundamental inescapable facts, inherent in the nature of things, which will inevitably make it impossible for any great living tongue—the native language of any people, however powerful and aggressive—to become, in the widest and most real sense of the word, international. First, the essential fact that no single such language, however broad, even the English, contains in its structure, vocabulary and idiom, enough of the elements of internationality already present and available to make it acceptable to, and easy of acquisition by, all other peoples. In all cases, the use of any single existing language internationally, involves the neglect of valuable, useful, beautiful, skilful forms of speech, possible in each of the others. The second, and perhaps the most serious fundamental obstacle exists in the mutual jealousy of nations, and national, provincial pride in one's own language. The experiences of Russia with Poland and Finland, of Austria with Hungary and Bohemia, of Germany with Alsace, are instructive.

To-day the nationalistic tendency is rampant in every tiny state and dependency in Europe; is fermenting among all the black and brown and yellow peoples over the earth who have heard of Japan's victory over a white race. And as the natural concomitant of this tendency, or indeed often as its main expression, we see dozens of petty dialects, once thought doomed to be swallowed up in a few of the great languages, now not only resisting furiously any such engulfment, but aspiring themselves to be great, to be spoken widely over the earth. Instead of Europe, for example, becoming more homogeneous in language with the development of the great consolidated states, it is apparently becoming more heterogeneous. The Bulgarians would Bulgarize the Balkans, including Macedonia, which the Greeks in turn are equally determined to Hellenize. Roumania and Servia have developed a national pride of language undreamed of in the seventies. Neither Russia nor Germany, despite the harshest measures, has succeeded in displacing Polish in its share of the dismembered kingdom. Every patriotic writer in Finland, in Lithuania, in Bohemia, rejects the great "world languages" for Finnish, for Lett, for Czech. Even the Irish are fervently reviving Erse. The Hollanders show no signs of a readiness to abandon Dutch for German, nor do the Walloons of Belgium intend to yield to the dominant French of their state.

As once in the early middle ages, writers in Italy and France, in England and Germany, disdained to express themselves in the common vulgar speech, owning Latin alone as worthy of putting on parchment. As later, Charles V. of German-Austria, told of how he talked in Latin to God, in Spanish to his family, in French to his courtiers, in Italian to the ladies, and—in German—to his horses only. So, not longer ago than in the last century, ambitious writers in the minor tongues, disdainful of the "peasant dialects" smacking of the soil, set their thoughts over into French, spoke in French, thought in French. To-day there is scarcely a tongue in Europe, however obscure or forgotten, that is not sedulously cultivating its own idiom in a conscious literary way.

On the edge of our world are Arabic, Chinese, Japanese, Persian, spoken by vigorous, populous national stocks, emerging into or fully participating in our complex international life, coming closer and closer every day by rail, steamer, telegraph and wireless, and to-morrow by the airships. Under the wise control of England, the native polyglot hordes of India are developing, preparing for a future nationality, which will not be English; in which the English language will remain what it is to-day, a foreign tongue. Over the huge domains of Mexico, Central and South America, millions upon millions of swarming people in the days to come will fill these lands with a vast Spanish and Portuguese speaking population. Will these then be among the "minor languages," to which their present position in Europe now relegates them?

What, then, of all these strong peoples who refuse to be assimilated, who are engaged in amplifying their own languages, and have no intention of meekly becoming absorbed by ours; who buy and sell, farm, mine and manufacture, produce and exchange increasingly, who share in the world's power of thought and expression, who are making or will make great discoveries in science, who will meet in conventional dress with our august selves, whether we like it or not, around the council tables of the globe?

Tell me, is any single national form of idiom adequate for all of these? Will any such be accepted by all of them? Will the whole world of human races, with its hundreds of languages and dialects, blunder along forever, chained in the shackles of polyglot speech?

Is a world language, then, really possible? As a universal language, in the sense of one that is to replace all others,—manifestly not, or if at all, only in some extremely remote epoch. How, then, shall we achieve the more immediate, rational and practical aim, of acquiring a single *auxiliary* medium of international speech, that shall replace no single language, however obscure, that shall remain forever neutral, and that shall be equally acceptable to all? Clearly, not by means of any existing national, "natural" tongue, but through the outright construction of an "artificial" language, which shall possess:

First, a vocabulary having a maximum of internationality in its root-words for at least the Indo-European races, living within or bordering on the confines of the old Roman Empire, whose vocabularies are already saturated with Greek and Latin roots, absorbed during the long centuries of contact with Greek and Roman civilization. As the center of gravity of the world's civilization now stands, this seems the most rational beginning. Such a language shall then have:

Second, a grammatical structure stripped of all the irregularities found in every existing tongue, and that shall be simpler than any of them. It shall have:

Third, a single, unalterable sound for each letter, no silent letters, no difficult, complex, shaded sounds, but simple primary sounds, capable of being combined into harmonious words, which latter shall have but a single stress accent that never shifts.

Fourth, mobility of structure, aptness for the expression of complex ideas, but in ways that are grammatically simple, and by means of words that can easily be analyzed without a dictionary.

Fifth, it must be capable of being, not merely a literary language, but a spoken tongue, having a pronunciation that can be perfectly mastered by adults through the use of manuals, and in the absence of oral teachers.

Finally, and as a necessary corollary and complement to all of the above, this international auxiliary language must, to be of general utility, be exceedingly easy of acquisition by persons of but moderate education, and hitherto conversant with no language but their own—in all a most formidable and exacting list of requirements. Is it possible, is it worth while to attempt to fulfill them?

The redoubtable Doctor Johnson, on visiting the Giants' Causeway in Ireland, remarked that "it was worth seeing, but not worth going to see." By a sort of analogy, there are very many people who would doubtless endorse the idea of an international tongue, were one achieved and at hand, but who would not, in the absence of one, consider the difficult game of its devising worth the candle of its getting. However, it is interesting to note that this very fascinating problem has occupied the minds of men to such an extent during the past two hundred years that no less than sixty distinct systems of international speech have been published within that period. That these attempts are not to be classified with the chimeras of perpetual motion and the like, we may assure ourselves from no less authoritative an opinion than that of the late Professor Max Müller, who gave it as his deliberate judgment that an artificial international language, was not only a necessary, but a practical and feasible project. That it is inconceivably difficult so to combine all the necessary features of such a language as to ensure its general adoption is evidenced by the fact that out of the sixty systems referred to, but two have actually succeeded in becoming more than printed theories. But two have ever been spoken and written by any number of people.

The first of these was Volapük, of which the author was Johann Martin Schleyer, born in Baden, Germany; a Roman Catholic curé, of a village near Constance, in Switzerland, where he published in 1880, a "Grammatik der Universalsprache für alle Erdbewohner." A few years ago he was still alive in Constance, having survived his language. His admirers credited him with a knowledge of eighty-three tongues. Volapük found an active propagator in Dr. August Kerchhoffs, professor of modern languages in L'école des hautes études commerciales of Paris. Beginning about 1886, it spread rapidly through France, and thence to the great cities of Europe and America. In 1889 there were 283 Volapükist societies scattered over the globe; its adherents were estimated at about a million; the number of published books on Volapük amounted to 316, of which 182 appeared in 1888 alone, and which were written in twenty-five languages. There were some twenty-five journals devoted to its propaganda, of which seven were published in Volapük alone. Three international congresses were held, the last one in 1889, in which the proceedings were in Volapük, and the language seemed to have become an established fact. But the same year saw the beginning of its decline, which was far more rapid than its rise. To-day Volapük is among the dead languages, possessing but a handful of faithful adherents.

The rapid rise and spread of Volapük, from 1886 to 1890, and its subsequent decline and ultimate extinction, demonstrate that the desire for an international language was universal, and that Volapük, in part, fulfilled the requirements. A study of that language clearly reveals the causes of its success, as well as of its failure. The grammar was simple and regular in construction, except in the multiplicity of its verb inflections. The letters had each but one sound; the words were absolutely phonetic; but the language had two fatal defects, the complexities just referred to in the conjugation of the verb, and the fact that the words were not formed on already existing international roots. Most of the root-words used were to be found in the Teutonic languages alone. All of them were mutilated beyond recognition; sometimes according to some phonetic rule, oftentimes according to a wooden arbitrary outline. Many of the words were actually "made up" meaningless sounds constructed according to a mechanical scheme of the author's. At best, Volapük looked unfamiliar, was inharmonious, ugly and uncouth in appearance and sound, and failed in the primary needs of an international tongue, except in the fact of possessing a grammar far more simple than any of the "natural" languages. As a matter of curious interest, and to illustrate some of the salient characteristics of the language, the Paternoster is given in Volapük, as follows:

"O Fat obas, kel binol in süls, paisaludomöz nem ola! Kömomöd monargän ola! Jenomöz vil olik, äs in sül, i su tal! Bodi obsik vädeliki givelös obes adelo! E pardolös obes debis obsik, äs id obs aipardobs debeles obas. E no obis nindukolös in tentadi; sod aidalivolös obis de bad. Jenosöd."

Note: Simple vowels with continental pronunciation; Umlauts as in German; consonants as in English, except c (tch), g (always hard), h (German ch), j (French ch), x (always ks), y (as in yoke), z (ts); tonic accent always on the last syllable of the word.

The second successful attempt at devising an international form of speech found issue in Esperanto, now apparently past the experimental working stage, and seemingly launched upon a rising tide of popularity and success. Some 100,000 people are now said to be able to correspond in Esperanto, and a large number of these speak it fluently. The number of the Esperanto groups seems to be increasing by leaps and bounds, and is placed at about three hundred thus far, distributed over all the four quarters of the globe. The propaganda has even reached Japan, which has fifteen hundred Esperantists, and a journal published in Japanese and Esperanto, and the very latest move appears to be the proposed invasion of China. In all about twenty journals are devoted to Esperanto, the organs of affiliated societies in each of the chief European states and in America. Seven magazines are published exclusively in the language, including some quite pretentious literary, illustrated and scientific monthlies. The London Chamber of Commerce has adopted Esperanto as a commercial tongue, and has organized classes and examinations in the language. Commercial schools in England, France, Germany and Sweden are offering courses, and in America, voluntary classes have been instituted in a number of our high schools and universities. In France, the language has received the approbation of the minister of war and marine, who commends it to the French military service. Finally, Esperanto has received the unqualified and enthusiastic endorsement and support of men eminent in language studies, the sciences and the arts, in every important country. Among these may be cited the late Professor Max Müller, of Oxford, and among living Englishmen, Professor W. W. Skeat and Sir William Ramsay; in Germany, the great name of Ostwald stands first, while in France the language seems to be enjoying among the intellectual élite a veritable *réclame*. Academicians, university professors, professional men, are flocking in imposing numbers to the ranks of the wearers of *la verda stelo*. Berthelot, Poincaré, Boirac, rector of the University of Dijon; General Sébert of the French army, indicate the personnel of the Esperanto movement in France, while in far Russia, rears the titanic figure of Count Leo Tolstoi, friend of humanity, as the champion of Esperanto in the name of universal peace and good-will among mankind.

There has already been inaugurated a system of Esperanto consulates throughout the world, with resident consuls, charged with the interests of Esperanto travelers. A "Centra Oficejo" (Central Office) has been established in Paris: an "Adresaro," or published list of the names and addresses of the adherents of Esperanto throughout the world, is issued annually, and a very considerable volume of literature, original and translated, already exists in Esperanto. Finally, two eminently successful congresses have been held: the first in Boulogne-sur-mer in France in 1905, and the second in Geneva, Switzerland, last August. At both of these congresses, hundreds of delegates from twenty-five or more nationalities met, conversed, transacted business in general. Numerous section meetings were held on various topics. Public programs were presented—theatrical, musical and literary—all in Esperanto. The new *American Esperanto Journal*, in its initial number of January, 1907, publishes an interesting letter from Dr. E. Y. Huntington, assistant professor of mathematics at Harvard, describing his experiences at the Geneva congress, from which extracts are as follows:

> When I arrived at the congress I had only a reading knowledge of the language; that is to say I had read some five or six hundred pages of Esperanto literature, but had never had an opportunity for speaking the language, or for hearing it spoken. Imagine my surprise and delight at finding that I could understand everything that went on from the very first day, and that within a few days I was able to use the language myself sufficiently well to spend a very profitable day conversing with a French philosopher, with whom I could have had no oral exchange of ideas without the aid of the new language. . . . Esperanto was for us both an indispensable means of communication. . . . The congress itself was a continual source of amazement to those of us who had been rather skeptical about the possibilities of an artificial language. The answer to all objections simply is—*the language works*. . . . The language was used at the congress for all the purposes to which a language can be put: general conversation, lively busy meetings, with spirited and eloquent extemporaneous debate, elaborate theatrical programs and church services. Any stranger dropping in at one of these Esperanto gatherings would certainly have supposed that he was in a foreign land where the people were talking in their own tongue. The experimental days are over; *the language works*.

The third congress, which will be convened in Cambridge, England, this month, is already arousing unusual interest.[1] The authorities of the University of Cambridge have proffered the use of the university buildings for the sessions of the congress, and the municipal council of the city of Cambridge has tendered the use of the city hall and other municipal buildings for administrative functions. In our own country, the growth of the Esperanto movement is surprising. All of the large cities have become centers of enthusiastic and rapidly growing groups.[2]

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[1] This article was prepared in January, 1907.

[2] During the writing of these lines, one of our most eminent journals, *The North American Review*, has allied itself definitely with the Esperanto propaganda, lending the inestimable prestige of its great influence to the interests of the language in America.

Finally, just what *is* Esperanto? Esperanto is the name given to a language composed by Dr. Ludovic Lazare Zamenhof, a physician of Warsaw in Russian Poland, born in 1859, in Bielostok in Russia, and now, therefore, in the prime of life. His first publication, issued in Warsaw in 1887 under the pseudonym of "Dro. Esperanto," literally translated, "one who hopes," bore the title "Langue internationale, Préface et manuel complet." The project, which had occupied the author from his youth, made scarcely any impression in the first years after its publication. Volapük then held the field, after the utter fiasco of which, Esperanto suffered from the effects of the general wave of skepticism, ridicule and obloquy that followed in the wake of its failure. It was indeed a considerable time before a new proposal for an international language could so much as gain a hearing in Europe. But Esperanto found a brilliant expositor, also in France, in the person of M. Louis de Beaufront of Louviers, to whose enthusiastic adhesion to the language in its early days is undoubtedly due to a very considerable degree its present success. To an almost fanatical enthusiasm M. de Beaufront conjoined extraordinary talent and ingenuity in the exposition of the merits and claims of Esperanto, and marked tact and cleverness in disarming its opponents. After ten years the effects of the efforts of the founder and his supporters began to be felt; and France soon began to teem with the Esperanto movement. To-day, what began as the desperate struggle of a forlorn little band of idealists, against contempt, ridicule and misrepresentation, and against almost hopeless odds, has risen to the proportions of a formidable affair of international significance, challenging the attention of rulers.

What now are definitely the claims of this remarkable tongue, the sole achievement of a single human being, wrought unaided by a single brain, a work of supreme genius? Without going into one slightest detail, let it be simply said that it answers fully to all the fundamental requirements above mentioned for an international language. Its grammar can be read and perfectly understood in an hour. The pronunciation is simplicity itself, as the letters have each but one simple sound, and the accent rests always on the same syllable, the penult. Seventy per cent. of the word-roots will be recognized at sight by a person of good education in English alone. The utter simplicity of its syntax might make it appear as though such a language must necessarily be bare, meager and inexpressive. On the contrary, as the result of its extraordinary structure, it is ample, rich and full, with much of the flexibility and mobility of English, much of the style and precision of French, not a little of the elegance and grace of Italian, while in great measure it has the full, sonorous quality of sound and imposing dignity of form peculiar to the Latin.

By way of illustration, compare the Paternoster in Esperanto and Latin.

Patro nia kiu estas en la ĉielo,
sankta estu via nomo;
venu regeco via;
estu volo via, kiel en la ĉielo,
tiel ankaŭ sur la tero.
Panon nian ĉiutagan donu al ni hodiau;
kaj pardonu al ni ŝuldoju niajn,
kiel ni ankaŭ pardonas al niaj ŝuldantoi;
kaj ne konduku nin en tenton, sed liberigu nin
de la malbono. Car via estas la regado,
la forto kaj la gloro eterne.

Note.—Vowels have continental sounds. Consonants as in English. ĉ = ch in church, otherwise c = ts; s = sh; final j as y. Each syllable is pronounced. Accent on the penult.

Pater noster qui es in coelis,
sanctificetur nomen tuum;
adveniat regnum tuum;
fiat voluntas tua, sicut in coelo,
et in terra.
Panum nostrum quotidianum da nobis hodie;
et dimitte nobis debita nostra,
sicut et nos dimittimus debitoribus nostris;
et ne nos inducas in tentationem, sed libera nos
a malo.

It will suffice to conclude with a translated extract from a recent French memoir, entitled, "La Langue Universelle" (Hachette et Cie., Paris, 1904), by Couturat and Leau. This memoir is the result of a comparative study and research into all the published systems of international speech appearing within the past two hundred years. The authors are two members of an official delegation, appointed by the International Association of Academies, which undertook, at the instance of the French Academy of Sciences, to consider the adoption of an international auxiliary language. Concluding their critique of Esperanto, the writers say:

In spite of its imperfections, easy to correct, the system of formation of words in Esperanto is one possessed of remarkable regularity and fecundity. It is this, especially, which contributes to give it the striking character of a "natural" language, of a living tongue, which good judges recognize in it. It is truly an autonomous language, which possesses intrinsic and unlimited resources, which has an original physiognomy and a genius all its own. . . . It is therefore not an "artificial" language, dried and dead, a simple replica of our idioms; it is a language capable of living, of developing, and of surpassing in richness, suppleness and variety the natural tongues. Finally, it is a language susceptible of elegance and style, if one admits that true elegance subsists in simplicity and clearness, and that style is but the order which one takes in the expression of thought.

INFANT INDUSTRIES[1]

By Professor T. D. A. COCKERELL
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THE university is, or ought to be, a nursery for young ideas as well as for young people. To an aged person like myself, there is something indescribably fascinating about a company of boys and girls. Who knows what they may do, what they may become? Do I not perhaps address myself to a Darwin, a Newton, or a Tennyson? Classes have grown up and gone away: not all their members have fulfilled our expectations; but yet, the harvest has been good—and who knows, who can tell, what is inherent in these *particular* green sprouts? It is the same with ideas as with people. Thoughts are born, mature, live their lives, struggle with one another, and finally reach their true position, if all is well. Alas! that is a large qualification, in either case. All may *not* be well; so much depends upon a favorable environment and that, of course, is what we are all trying to create.

There is one important difference between our young people and our young ideas. The former come to us at an age which—well, which seems to them quite grown up. The latter are often, we hope, born upon the premises, and raised by hand with tender care during their helpless infancy. Like other infants, they must not be forgotten, even for a little while, and they are subject to all sorts of infantile disorders. Unlike human infants, they have the unpleasant habit of destroying one another, and we, their nurses, are so heartless as to actually encourage this internecine conflict. Nevertheless, we prize them highly, and actively resent the sneers of passers by, who either have none of their own, or only horrid little brats we would not condescend to look at.

When very tender, they must often be kept at home. I used to be a student at a medical school in London, where we had a very original demonstrator of comparative anatomy. The results of our labors were tested in examinations held, not by the teachers, but by quite other and more aged professors. So our mentor used to say: "You see, gentlemen, this is so and so, but I only found this out the other day, and you must on no account tell it to the examiners, or they will give you zero." You will appreciate the immense advantage of being ex-

[1] Chapel address to the students of the University of Colorado, April 29, 1907.

amined by your own professor, all of whose heresies can be produced and accepted as current coin—perhaps even a little above par. Oliver Wendell Holmes justly remarked that you can not lift a stone without creating a panic among some of the centipedes and other crawling things which enjoyed the darkness it provided. Infant industries in the intellectual field are apt to be destructive of more things than toys, and so they are justly feared by the powers that be. There is this curiously complicated situation, that whereas intellectual progress is not merely advantageous to a nation, but is in this day of the world essential, it is of positive disadvantage to that numerous company to whom change means injury or destruction. This, however, is exactly what may be said of infants of flesh-and-blood: they are costly, troublesome, often noisy and ugly, and quite unable to do anything useful to compensate for all the injury and expense they involve. In the latter respect, they are much worse than their psychological parallels, for these are usually capable of rendering some service at a very early day. Why, then, do people ever raise children at all? Simply because they have learned to love them; this sentimental attitude has undoubtedly saved the race from extinction, and may be relied upon to do so for some time to come.

I see nothing for it, but the cultivation of a like feeling toward our beloved progeny of the mind. It should be one of the chief aims of university training, it seems to me, to cultivate an appreciation of progress, and an ardent feeling—yes, a sentimental affecting for these babes of the intellect. We should be not merely willing, but happy, to struggle hard to give them birth, to watch them daily, and if need be walk the floor with them at night. Many a man has shown just this devotion, has remained through the small hours with his eye glued to the microscope, or has refused to be comforted while the threads of his argument were still in a tangle. To most, I fear, all this must seem fanciful. I am not so quixotic as to hope that the beginnings of change will ever be widely understood. Nobody supposes that the parents of Shakespear knew the extraordinary value of the little wailing thing they had; nor it is possible for the originators of lines of thought to see where they will lead—much less the general public. Not only are we unable to rightly value our infants, but we have an uncomfortable feeling that some of them will do us no credit—or if we have not that feeling, some of our friends entertain it on our behalf. The truth is, we can not tell the good from the bad at a very early age, and the experience of mankind indicates that a charitable attitude is the wisest. Some of the best thoughts ever born into this world have appeared nonsense to the best friends of their parents.

I may be permitted to cite some instances in which ideas, cherished for the mere love of them, have done unexpected things in their mature years. Somewhat more than forty years ago one Gregor Mendel, an Austrian priest, was raising garden peas. Instead of eating them, as you and I would have done, he observed and recorded the facts of inheritance they served to illustrate. Among other things, he discovered that in the case of pairs of opposing characters possessed by the parents of any given generation, some would be inherited in such a manner that half of the offspring, while apparently possessing only the character *A*, would in reality have also the other one, *B*, in their make-up—not visible at all, but ready to appear in another generation. That is to say, we may be indeed of the Jekyll-Hyde type, only the Jekyll alone appears in us, the Hyde in some of our children or *vice versa*. Without going into particulars, you can easily see that if, under such circumstances, the visible or dominant character is discriminated against by selection, the race possessing that character disappears; but as Dr. Shull has recently remarked, discrimination against the recessive or hidden character is ordinarily impossible, since in two thirds of the cases it is not visible at all, but is stored away in the germ cells to appear only in the next generation. The various important economic results flowing from the Mendelian researches—which were overlooked by naturalists for forty years, have been set forth in various places, but I may call attention to the possibility that certain forms of both virtue and vice, equally discriminated against by our modern civilization, are Mendelian recessives, and that is why they continue to appear in spite of everything. We stone the prophets, but it has not occurred to us to stone also the brothers and sisters of the prophets.

A few days ago, Dr. J. C. Arthur, of Purdue University, our foremost student of plant rusts, was here in Boulder. He told me something about his researches on the parasitic fungi of the different species of sunflower. It seems that certain sunflowers, which we will call *A*, have rusts which appear to grow exclusively upon them; while others, which we term *C*, are similarly afflicted. European mycologists had found that these parasites could not be transferred from *A* to *C*, or *vice versa*, and so had assumed that they were different species of fungi. But Dr. Arthur made the remarkable discovery that if the rust from *A* was sown on the common sunflower, which we will now term *B*, it would grow there, and would produce spores which would grow quite successfully on *C*. The process could also be reversed, causing the rust of *C* to grow on *A*, after a sojurn upon the intermediate *B*. It is greatly to the honor of the authorities of the Indiana Experiment Station, that they have—as I believe—supported Dr. Arthur in this work of his, and appreciated its value. In some places known to me, it would be quite otherwise, and I do not doubt that some of you are wondering whether, after all, this is a mere botanical curiosity.

However, putting aside the extraordinary scientific interest of such discoveries, and their bearing, ultimately, on the whole fabric of human thoughts; you will see readily enough that if a rust fungus can be transferred to a previously immune host through an intermediate form the planting of such a form in a certain region might be the cause of the ruin of a whole crop of wheat, oats, barley, or what not. Agriculturists have long sought, and thanks more especially to the knowledge derived from Mendel's researches, are learning how to isolate rust-proof types of cereals. In this way the pest may be overcome, but the vantage gained may again be lost in ways which would never be suspected, and could not be prevented, but for Dr. Arthur's illuminating researches.

Mr. W. L. Tower, of the University of Chicago, has been for many years conducting breeding experiments among beetles, choosing for that purpose the Colorado potato beetle and its immediate allies. Only the first part of his results has been published, but it is enough to show that he has found out some exceedingly interesting and important things and thrown new light on other matters not entirely new. For example, in breeding the beetles, he found that through a number of generations, the selection of extreme individuals (say dark, or light) for breeding did not sensibly modify the race. But by a process of very elaborate and careful breeding from isolated beetles, he discovered that sometimes a character was inherited fully, sometimes not to any appreciable degree, that is to say, it was possible to have two parents, *AA* and *AB,* looking exactly alike, but the first having, the second lacking, the property of producing offspring all closely similar to itself. The importance of such facts from an economic standpoint are hardly to be overestimated. Through such researches as those of Tower and Mendel, we are coming to understand why it is so difficult to improve a race by merely choosing those individuals which superficially appear to be of a desirable kind. It is necessary to isolate them, and test their properties through the character of their offspring, in order to separate pure races.

I have chosen only a few striking cases, and have said nothing about the infant ideas of our own vicinity. At some future time it may seem worth while to get up a local baby-show; the more so because, I regret to say, many of the infants known to me are lacking nurses, and I do not know of any hospitable door steps on which to leave them.

Ideas are not merely born once, but they suffer new births in the minds of many persons. In truth, they are not precisely repeated, but in each reincarnation are a little modified or augmented, so that the thought of every person about a given subject has its own individuality. This, however, presupposes that the child is alive, and not still-born. If it has any vitality, it will call attention to that fact by metaphorical kicks and screams, quite as much as any ordinary infant. In all of this, the analogy with living people is again complete, for we ourselves are not entirely new, but merely repeat, with all-important modifications—the forms of our ancestors. The old text-book must not be discarded. It is full of information—and information is the food upon which ideas subsist. Many a good child of the intellect has been starved or warped because the fact-food supplied to it was deficient or bad. Adulterated fact is as bad as adulterated butter, sugar or lard; we can not have it chemically pure, I suppose, but woe to him who intentionally mixes wrong ingredients. The scientific men is devoted to truth; he is a pure-food man on the intellectual plane, and those who distort the truth for the purpose of warping the public ideas, are to him the worst of living creatures.

However, just as food, pure or impure, is of no use unless it is consumed, so information unapplied to the nourishment of thought is thrown away. I fear there is too much such waste among us, for the reason that we have not yet learned to think. The other day I passed two very little children, a boy and a girl, on their way to the University Hill School. The boy said to the girl, with the air of one communicating a most interesting fact, "Do you know, t, h, e, spells the"! Here was an example of the true spirit of science, the pleasure in the apperception of a new thing in its relation to something else. I must confess that the plane of this conversation was higher than that I usually overhear on the university campus.

THE FUTURE OF ECONOMIC ENTOMOLOGY

By Professor H. T. FERNALD, Ph.D.

AMHERST, MASS.

IT is now about three quarters of a century since the economic aspect of entomology was first presented for consideration in America, and this is perhaps an opportune time to survey the progress which thus far has been made, and in some degree to consider its future possibilities.

A careful examination of the writings of T. W. Harris, who may be termed the father of economic entomology in this country, shows several suggestive points. In his day the modern methods of using insecticides had not been discovered, and most of the treatments he suggested are included in the phrases hand-picking, whitewashing, cold water, fall plowing, cutting out borers and burning stubble for grain insects. Even in the cases where he advised the use of red pepper and tobacco, and soap or potash washes, the underlying thought seems to have been as much along the line of repelling as of destroying pests, and the idea of compelling insects to consume poisoned food appears to be entirely absent from his writings. Fumigation, too, though suggested in one instance, seems hardly to have had its possibilities appreciated, and it is probable that the most valuable contribution he made to the subject was the thought, quite new in this country, that insect depredations need not necessarily be accepted as in accordance with the will of God, but that active measures to prevent or reduce loss were possible.

Much has been learned since the days of Harris and new methods of control have replaced some of those he suggested. But it is discouraging to note that with many of our insect pests we stand to-day where we did then, and hand-picking, whitewashing, cutting out borers and fall plowing still occupy a prominent place in the entomological pharmocopœia.

Probably the most potent influence in the development of modern economic entomology was the spreading of the Colorado potato beetle to the east, and the resulting discovery that this pest could be controlled by the use of Paris green. That any insect consuming leaf tissues could be destroyed by applying a poison to be taken into its body along with its food was a discovery the credit for which will never perhaps be correctly assigned, but which marks the beginning of a new era in economic entomology, and rapid developments along this line followed, resulting in the formulation of the general principle of the utility of stomach poisons. This has led to the investigation of many materials from the standpoint of their value as insecticides, together with determinations of their relative efficiency in different cases, how to control their effects and how they may best be applied, resulting in the development of spray pumps, nozzles and spraying apparatus in general.

Closely following the discovery of stomach poisons as insecticides came that of contact poisons for sucking insects, for though Harris had suggested soap solutions in one or two instances the general principle had until this time failed to be formulated. Here, too, investigation progressed rapidly, developing different materials as contact insecticides varying in strength and in their range of application until this field may now be considered to have been well explored.

Fumigation, as a method of control, during all this time remained almost unnoticed, its limitations being apparently so great, and the fumigants themselves being so mild as to give little promise of results of value. But during the last twenty years the utilization of gas-tight tents, and of hydrocyanic acid gas and carbon disulfid has shown that this method of control has a far wider range of applicability than was formerly supposed, and fumigation is now perhaps as well developed and its possibilities as thoroughly understood as is the case with stomach and contact poisons.

During the last three quarters of a century the ravages of insects have so greatly increased as to attract much attention to the subject, and many persons have become specialists in economic entomology. Numbering less than half a dozen in 1850, we now find more than five hundred workers, each year publishing thousands of pages on the results of their investigations. Large societies now hold regular meetings at which the problems of economic entomology are discussed; and the subject, once of little importance and of which almost nothing was known, has now become a large and important branch of applied science, with more positions waiting than there are competent persons to fill them.

The rapid increase in the losses caused by destructive insects, which has focussed so much attention on economic entomology is difficult to state accurately in figures, but was estimated in the report of the U. S. Commissioner of Patents (then in charge of the agricultural work of the government) in 1850, to be at least twenty millions of dollars, while other estimates of that period made in terms of the total crop value placed the loss at about ten per cent. Since that date conditions have changed materially and are continuing to change for the worse. The development of speedy commerce has enabled many of the most serious pests of foreign lands to reach and establish themselves here, till in addition to our own native insects we have also one hundred or more from abroad, many of them developing destructive powers greater than in their native lands. The intensive agriculture and continuous acreage methods of recent years directly favor their rapid increase, and with the gradual reduction in numbers of our insectivorous birds one great check to their increase has been removed.

The result has been what might be expected. Estimates of the average annual loss by insects calculated at eighteen per cent., are now considered as about correct, and this loss on the basis of the United States government crop estimates for 1906 would be considerably over a billion dollars each year.

Nor is the end in sight. The pests of other lands are not yet all represented in the United States, though new ones arrive nearly every year. Agriculture is becoming more intensive, larger areas are being tilled, furnishing a more abundant and easily discovered food supply, and in spite of a healthy growth of interest in preserving our insectivorous birds, it is questionable if the developments connected with an increasing density of population will permit their preservation in any great numbers for more than another century.

This increase of loss has also occurred in spite of all the efforts of the economic entomologists, each one of whom can but acknowledge that while his efforts have not been in vain, the battle is nevertheless going against him, for in spite of all his efforts losses are becoming greater, insects more abundant and ultimate defeat seems certain, unless new and more effective methods can be brought into use in the struggle.

At the present time the economic entomologist is much in the same position as that of a physician who gives his prescriptions, but finds that many are never even taken to the druggist to be put up, while others, though prepared, are never taken and still others are taken but once. Many a crop is entirely lost by the neglect of its owner to apply the proper treatment and the value of many others is lessened one half or even three fourths by careless, shiftless work generally followed by entire failure to apply farther treatment because the first one being improperly or poorly made did not give the anticipated results.

If such are the existing conditions, what of the outlook? How long can this continue before greater crop destruction by insects and fungi, and an increasing population produce famine?

To these questions it is impossible to give decisive answers, though it is probable that many years are still between us and famine caused by insect ravages. But if an improvement of present conditions is desired, it would seem that it must come through the adoption of means by which spraying can be made more acceptable, or by the development of new methods of control.

The remarkable apathy of the crop producers of this country toward their insect foes, and their pronounced disinclination to carry out methods of treatment is an attitude which should be reversed as quickly and vigorously as possible. Much of this change must wait for a new and more intelligent generation, better educated by our colleges and by training in agriculture in the elementary schools. Many a farmer to-day, however, would gladly spray or otherwise treat his crops if he knew how, but the details of the processes as usually printed serve only to confuse him, and the necessity for handling and mixing chemicals accurately he feels to be beyond his powers. To help this large class it would seem desirable for each state to organize a traveling force which should go from place to place and at each show how to prepare and apply the different materials most commonly used, together with the different kinds of apparatus for different purposes, thus enabling any one to see for himself how to make and apply the treatments needed.

It is very possible that this plan may fail to accomplish the desired results, for farmers as a class are notoriously slow to accept new ideas and new methods. Still it is one which has many elements of promise and should receive a thorough trial in all parts of the country before being rejected.

But where does the economic entomologist stand if this plan fails? For years he has urged, taught and demonstrated spraying methods as effective, and he knows that he is correct. But when his advice is for years persistently rejected by a large proportion of the people, as is still the case, it is certain that the time has now come to place economic entomology on a broader and more scientific foundation.

To accomplish this other lines of work are possible, none of which have as yet been given sufficient consideration. The entomologist who would be successful must soon study more fundamental problems rather than questions of petty detail, for if the fundamental principles are once correctly enunciated the details will then become merely individual examples and can be quickly and easily solved.

If man can not be relied upon to combat his insect foes, it is not improbable that nature may be induced to take up the warfare. In some cases it seems probable that careful plant breeding will result in the production of varieties resistant to the attacks of insects, and along this line experimental research promises much. The development of new plant forms which has been made so prominent recently by the experiments of Burbank and others is very suggestive, and the possibility of producing varieties not attacked by insects seems to have already been demonstrated in one or two cases to some extent.

In the case of insects having numerous food plants this method becomes less feasible, and here a scientific study of what may be termed entomological parasitology may prove useful. We must recognize that parasitic protection is never more than partial, but even a partial destruction of insect pests is of great value. The problem is beset with difficulties because of the existence of parasites on the parasites and by many other factors, and a single wrong conclusion such as the recent statement that the *Ceratitis* on peach was effectually controlled by parasites in Brazil would be sufficient to discredit this entire method of investigation. For this reason only the best trained scientists especially educated for this line of work should attempt it and it would seem in many ways an appropriate work for the government to take up as it would necessitate much travel and expense, and its benefits would not be restricted to any one state.

If economic entomology is to attain success during the present century then it will be by inducing a more general adoption of the methods of treatment now known but not used generally enough; by the production of new, pest-resistant varieties of plants by experimental plant breeding; and by utilization of all the parasitic forces the world has available, establishing the parasites where their services are most needed and as free as possible from their own enemies. The old methods have proved too nearly useless because they have been so little adopted. A new departure must be taken and the world is waiting for a new Moses to lead the way out of the wilderness.

THE INSTINCT OF FEIGNING DEATH

By Professor S. J. HOLMES
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THE so-called instinct of feigning death is one which is very widely distributed in the animal kingdom. It crops out sporadically, as it were, in forms which are but very distantly related, and hence it must have been independently evolved a great many times. The expression feigning death is a misleading one to the extent that it is apt to give rise to the idea that the animal consciously adopts this device with the intent to deceive. While it is probable, however, that among the higher animals which sometimes feign death there may be an attempt to mislead their enemies, it is quite certain that among the insects, spiders and other low forms there is no such aim in the creature's mind if we grant (what some naturalists are disposed to deny) that these animals have minds. The veteran French naturalist, Fabre, who has devoted the leisure periods of a long life to the enthusiastic study of the ways of insects, performed several experiments on beetles in order to ascertain if the duration of their feint was in any way affected by his own presence or movements. Most of Fabre's observations were made on a large scarab beetle. When handled the beetle would throw itself into an immobile state with its head bent down and its legs drawn in close to the body. It would remain in this attitude perfectly quiet for several minutes—sometimes for over an hour. Its awakening would be first manifested by a slight trembling of the feet and a slow oscillation of the antennæ and palps; then its legs would move about more vigorously, and finally the insect would arise and scamper off. Seized again, it would repeat the performance several times in succession, the duration of the feint often increasing with successive trials. Finally, as if wearied, or convinced that the ruse were vain, the beetle would refuse to feign longer.

Were the feints attempts to deceive its captor by simulating death? Fabre placed the insect on its back, went to a distant part of the room and remained perfectly quiet. The beetle still lay as usual. He then went out of the room, carefully looking in at intervals to watch the course of events. Still the same immobility. In other cases he covered the insect so that it could not see out and then quietly went away. This was also found to make no difference. In fact, whether the insects were surrounded by sounds and sights of moving objects or entirely excluded from these influences made no difference in the average length of time they would remain in a motionless condition. Similar experiments have been made on other insects by different observers, who have all arrived at the conclusion that conscious deception plays no part in the process.

The attitudes assumed by insects and other forms when feigning death are usually quite different from those of dead specimens. This general fact was pointed out by Darwin, who says that "I carefully noted the simulated positions of seventeen different kinds of insects (including an *Iulus*, spider and Oniscus) belonging to distinct genera, both poor and first-rate shammers; afterward I procured naturally dead specimens of some of these insects, others I killed with camphor by an easy slow death; the result was that in no instance was the attitude exactly the same, and in several instances the attitudes of the feigners and of the really dead were as unlike as they possibly could be."

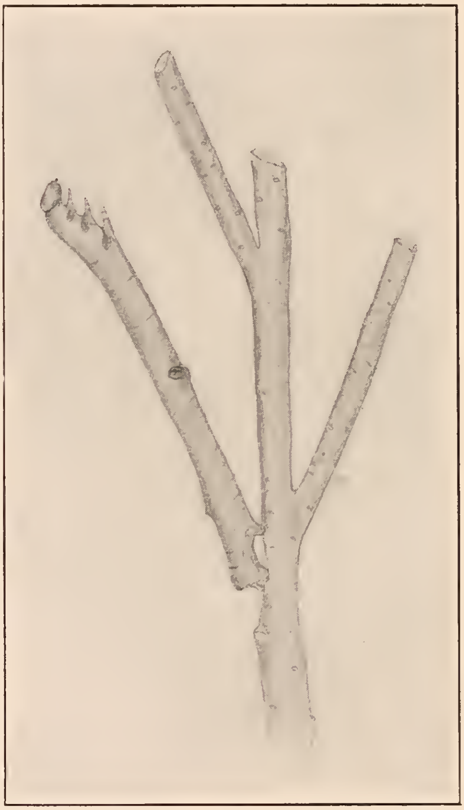


Fig. 1. Larva of a Geometrid Moth attached to a Twig.

The attitudes of animals in the death feint are frequently very characteristic. Many beetles as well as other forms feign with the legs drawn up to the body and the antennæ closely appressed, so that the whole insect assumes as compact a form as possible. The woodlouse, *Armadillo*, rolls itself up into a ball with its legs drawn into the center, a habit which has doubtless caused the name pill-bug to be given to this crustacean. A beetle, *Geotrupes*, according to Kirby and Spence, "when touched or in fear sets out its legs as stiff as if they were made of iron wire—which is their posture when dead—and remaining motionless thus deceives the rooks which prey upon them. A different attitude is assumed by one of the tree-chafers probably with the same end in view. It sometimes elevates its posterior legs into the air, so as to form a straight vertical line, at right angles with the upper surface of its body."

Spiders usually feign by folding up their legs, dropping down and remaining motionless. The caterpillars of some of the geometrid moths have the curious habit of attaching themselves to a branch by their posterior legs and holding the body straight and stiff at an angle to the stem, thus forming a remarkably close resemblance to a short twig. Frequently the deceptiveness is increased by a marked similarity in color to that of the branch to which they are attached.

While in most cases a species has a particular attitude which it maintains when simulating death, there are some forms which feign in whatever posture they may be in when disturbed. A good example of this is afforded by the water-scorpion, *Ranatra.* This insect has the two hinder pairs of legs, which are employed in walking and swimming, very long and slender; the first pair are fitted for grasping the small aquatic animals on which it feeds and are carried straight out in front of the body. It is only necessary to pick one of these insects out of the water to throw it into a stiff, immobile condition which usually lasts several

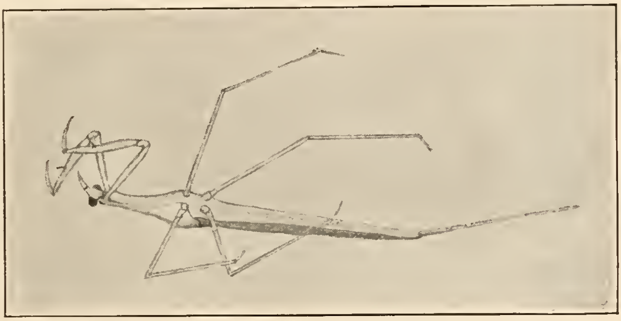


Fig. 2 A Water Scorpion, *Ranatra,* Feigning Death

minutes and sometimes for over an hour. The legs may be closely pressed to the body so that the creature resembles a stick, or they may stand out at right angles to it, or be bent in any position, some in one way and some in another, depending upon how they happen to lie when the feint began. And no matter how awkward the position, it is rigidly maintained until the feint wears off. I have found that young *Ranatras,* the first day they emerged from the egg and while their appendages were still soft and easily bent, showed the same death-feigning instinct as the adults, although they did not persist in it for so long a time. It is a curious fact that the mature insects can not by any sort of manipulation be caused to feign death while underwater; but as soon as it is in the air it can be caused to feign repeatedly; sometimes a slight touch is all that is necessary to throw it into a rigid state of an hour's duration.

Death feigning does not seem to occur among the lower invertebrate animals such as the Protozoa, Cœlenterates, Molluscs and worms, although some of them may exhibit reactions which are prophetic of this instinct. Among Crustaceans the instinct in its fully developed form is quite uncommon. Some years ago I described the death-feigning of certain species of terrestrial amphipod crustaceans which are frequently found on sandy beaches near the seashore. On account of their peculiar hopping movements these crustaceans are commonly known as sand-hoppers or sand-fleas, although they have of course no relation to the ordinay fleas of human experience. One of the largest species of sand-hopper, *Talorchestia,* is common along our Atlantic coast, where it lives during the day in burrows made in the sand, coming out only at night to feed upon the seaweed and other material washed ashore by the waves. When the Talorchestias are dug out of their burrows,

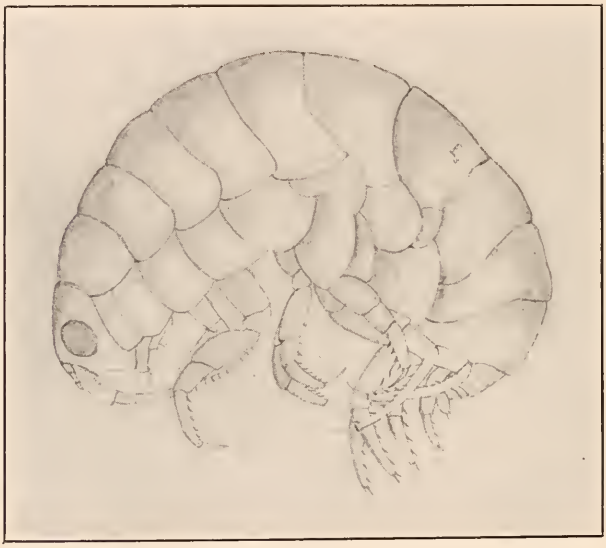


FIG. 3. A SAND-FLEA, *Talorchestia,* IN THE DEATH FEINT.

they usually lie curled up with their long antennæ bent under the body and their legs drawn up so as to assume a compact form. They will lie in this way for several minutes, when they may be seen slowly to relax; the legs then move about, and soon the creature hops away by a sudden extension of its abdomen. When caught in the hand they will feign death again, and repeat the performance many times in succession. Other species of sand-hoppers exhibit the same instinct, though less perfectly, and there are traces of it in many of the reactions of their aquatic relatives.

The various species of wood lice exhibit the instinct of feigning death in various degrees. Some species are able to roll up into an almost perfect ball and will remain in that state for a considerable time. Other species curl up, but make only a very imperfect approximation to a sphere, and they may not maintain this attitude but for a short period. Some myriapods when disturbed curl up in much the same way. Among spiders death-feigning is not uncommon, especially among the orb weavers.

It is among the insects that the death-feigning instinct reaches its fullest development, occurring to a greater or less extent in most of the orders. It is especially common in beetles and not unusual among the bugs, but it is quite rare in the highest orders such as the Diptera or flies, and the Hymenoptera, or the ants, bees and their allies. It occurs in a few cases among butterflies and moths, both in the imago as well as the larval state. The instinct is exhibited in different species in all stages of development from a momentary feint to a condition of intense rigor lasting for over an hour. Some insects may be severely mutilated, or, according to De Geer, even roasted over a fire before they will cease feigning.

Among the vertebrate animals death-feigning has been observed only rarely in the fishes. In the Amphibia it is not exhibited in the striking way it occurs in insects and spiders, although frogs and toads may be thrown by the proper manipulation into an immobile condition more or less resembling it. A phenomenon apparently related to the death feigning of insects has long been known in certain reptiles. Darwin in his "Journal of Researches" describes a South American lizard which when frightened "attempts to avoid discovery by feigning death with outstretched legs, depressed body, and closed eyes; if further molested it buries itself with great quickness in the loose sand." The Egyptian snake charmers by a slight pressure in the neck region are able to make the asp suddenly motionless so that it remains entirely passive in the hands of the operator. And similar phenomena have been found in other species.

In birds the instinct crops out only here and there. A few summers ago when on the island of Penikese I was somewhat surprised to find the instinct well developed in the young terns which were hatched out in abundance on the hillsides. For a short time after being hatched the little downy fellows betray no fear of man and will cuddle under one's hand in perfect confidence. When the birds become larger and acquire their second coat of feathers the instinct of fear takes possession of them and they run and hide in the grass when you approach. Here they lie perfectly quiet; you may pull them about, stretch out their legs, necks, or wings and place them in the most awkward positions, and they will remain as limp and motionless as if really dead. They will even suffer their wing or tail feathers to be plucked out one by one without a wince. But all of a sudden the bird becomes a very different creature. It screams, pecks and struggles to escape. I have made several attempts to make a bird feign death a second time, but never met with success. According to Couch the land rail and skylark feign death, and Wrangle states that the wild geese of Siberia have the same habit during their molting season, when they are unable to fly. Hudson states in his most interesting "Naturalist on the La Plata" that the common partridge of the pampas, when captured, "after a few violent struggles to escape drops its head, gasps two or three times, and to all appearances dies. If, when you have seen this, you release your hold, the eyes open instantly, and with startling suddenness and noise of wings, it is up and away and beyond your reach forever."

In mammals the instinct is so well shown in one of the lower members of the group, the opossum, that the expression "playing possum" is familiar to every one. Foxes when trapped or hard pressed often drop down limp and apparently lifeless and will even endure a good deal of maltreatment without making any response. Hudson records that he was "once riding with a gaucho when we saw, on the open level ground before us, a fox not yet fully grown standing still and watching our approach. All at once it dropped, and when we came up to the spot it was lying stretched out, with eyes closed, and apparently dead. Before passing on my companion, who said it was not the first time he had seen such a thing, lashed it vigorously with his whip for some moments, but without producing the slightest effect."

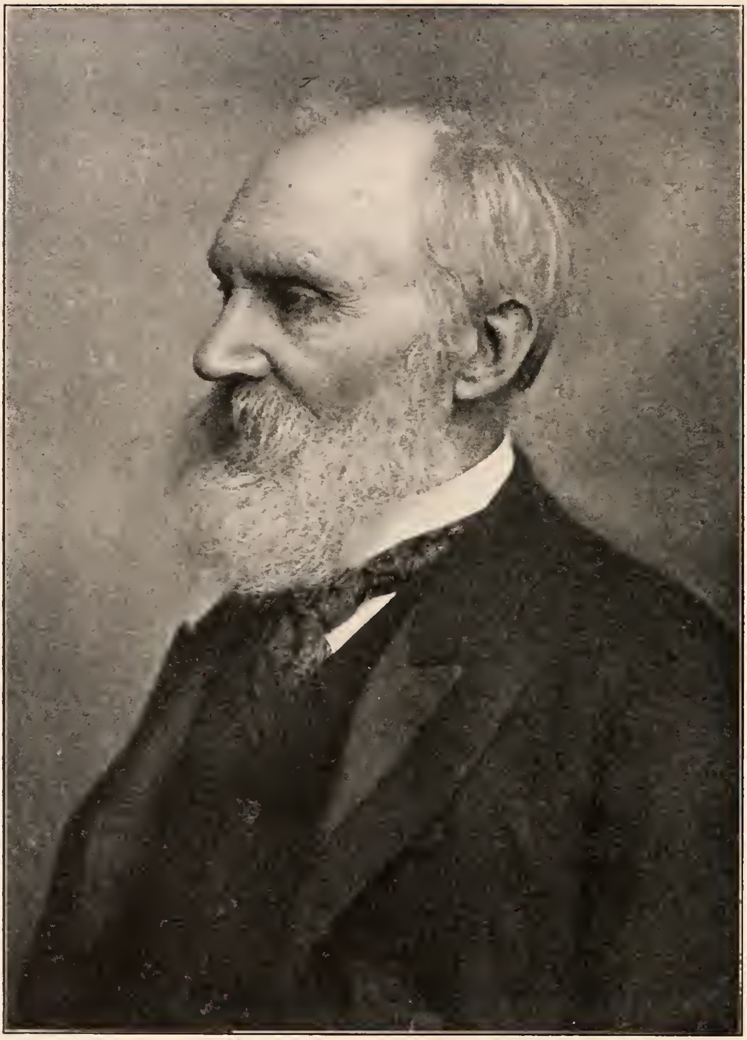
Mr. Morgan in his book on the beaver gives the following instance on what he assures us is excellent authority: "A fox one night entered the hen-house of a farmer, and after destroying a large number of fowls, gorged himself to such repletion that he could not pass out through the small aperture by which he had entered. The proprietor found him in the morning sprawled out upon the floor apparently dead from surfeit; and taking him up by the legs carried him out unsuspectingly, and for some distance to the side of his house, where he dropped him upon the grass. No sooner did Reynard find himself free than he sprang to his feet and made his escape." Dogs are frequently deceived by this ruse of the fox and doubtless foxes have many times owed their lives to its aid. It has been often noticed that if one withdraws from a fox when it is feigning it may be seen to slowly open its eyes, then raise its head and carefully look around to see if its foes are at a safe distance, and finally scamper off.

While in insects the instinct of feigning death is probably a simple reflex reaction to outer stimuli, it is doubtless associated in birds and especially mammals with a tolerably acute consciousness of the situation. It involves a more or less deliberate intention to profit by the deception, yet at the same time it is probably not a result of conscious reflection. The instinct is there, or else such a course of action would not occur to the animal's mind. Were it otherwise it would be difficult to understand why the ruse is adopted only by certain species while many others, equally intelligent and for whom it would be an equally advantageous stratagem never manifest it. There can be little doubt that a fox which slowly opens its eye and warily looks around is acting with an intelligent appreciation of his predicament, but it is not to be inferred that he could have reasoned out his course of action did not an innate proclivity in that direction form a part of his instinctive make-up.

The physiological condition in what is called death-feigning is quite different in different forms. In most of the lower animals it is characterized by a tetanic contraction of the muscles. The attitudes assumed by many forms, such as rolling into a ball, keeping the legs and other appendages drawn close to the body, or in some cases holding them straight and rigid, are such as can be maintained only at the cost of considerable muscular effort. If a *Ranatra* is picked up by one of its slender legs it may be held out horizontally for a considerable time without causing the leg to bend. It is as if a man were seized below the knee and held out straight, face upward, without causing the knee to bend; only the legs of a *Ranatra* are several times more slender than those of the most attenuated of the human species, and the muscular tension which the insect maintains must therefore be intense.

The death feint of insects and other low forms is not entirely dependent on the brain. It is due rather to a general physiological state of the animal. I have found that the posterior part of the body of a *Ranatra* can still be induced to feign death, though less perfectly, when entirely removed from the head and prothorax. When it would come out of the feint a few light strokes would cause it to feign again. It has been found that spiders also may still feign after entire destruction of the brain.

The instinct of feigning death is doubtless closely connected with much of what has been called hypnotism in the lower animals. Crayfishes, frogs, lizards, certain snakes and many birds and mammals, may by a very simple process be thrown into an inactive condition from which they are not readily aroused by external stimuli. In ordinary death feigning the animal falls into its immobile state upon slight provocation; a touch, or even a jar is sometimes all that is necessary. In the so-called cases of hypnosis more or less manipulation is necessary. The exciting cause in both cases is generally some form of contact stimulus. In the hypnotism of animals, as Verworn and others have shown, there is diminished reflex irritability, and usually tonic contraction of many at least of the muscles. Similar phenomena are observed in the death feigning of many forms, some of the insects showing a lack of responsiveness that is truly remarkable. In a water-scorpion that is feigning death the legs may be cut off one by one, or the body cut in two without eliciting the least reaction from the unfortunate victim. We can only speculate at present on the condition of the nervous system which makes such a result possible.



Lord Kelvin.

THE PROGRESS OF SCIENCE

LORD KELVIN

THE tomb of William Thomson, Baron Kelvin of Largs, now stands beside that of Darwin in Westminster Abbey, and a great epoch in history is closed. The nineteenth century will remain preeminent for the supremacy of science and for the advance of industrial democracy. Great Britain more than any other nation has led these movements, and no other of its great men so completely typifies them as he who ranged from cosmic speculations to industrial inventions, who brought together mathematical physics and practical engineering.

While Kelvin retained to the age of eighty-three years much of the vigor, keenness and intellectual curiosity of youth, he belongs in a sense to the middle of the nineteenth century rather than to the more complicated period of its close. For the grandson of an Irish peasant farmer to amass great wealth, discard his plebian name and take a seat in the house of lords is a social ideal of the earlier rather than of the later democracy. So Kelvin's science was static of the forties. He liked models that he could visualize; he did not care for the doctrine of evolution; even in his own field the researches of others did not greatly affect him. This is perhaps typical of genius, especially mathematical genius, which seems to develop early, to be likely to be hereditary and to be comparatively unaffected by external conditions.

Kelvin's father, without early opportunities, became professor of mathematics in Glasgow University, and his brother was professor of engineering there. Kelvin was appointed to the chair of natural philosophy at the age

LORD KELVIN,
then William Thomson, at the age of twenty-two, when just elected to the Chair of Natural Philosophy at Glasgow.

of twenty-two. He matriculated as a student at the age of eleven, and at the age of seventeen began to publish papers on the mathematical theory of heat. Migrating to Peterhouse, Cambridge, he became second wrangler. Within four years Stokes, Cayley and Adams had been senior wranglers, illustrating the precocity of mathematical genius and the mathematical activity of Cambridge at that period. For fifty-three years Kelvin was professor of natural philosophy at Glasgow. Like Helmholtz he was not a good lecturer, but like his great German friend he exercised an enormous influence on the progress of science directly as well as by his published work. The jubilee of his professorship was adequately celebrated in 1896; from the volume giving some account of it, the portraits here reproduced are taken. Kelvin was president of the Royal Society and of the British Association, and was active in their work, rarely failing to take a leading part at the annual meeting of the association. All the highest scientific honors were of course conferred on him. He was twice married, but leaves no issue.

To the general public Kelvin is best known for his share in submarine telegraphy, for his improvements in the compass, for his machine for taking soundings and for other inventions, scores of which he patented. To the electrician and the engineer many important instruments and improvements in methods of measurement will occur, such as his three electronometers, his mirror galvanometer and his syphon recorder. With Professor Tait he began a "Treatise on Natural Philosophy," which has become a classic for parts of mechanics. His popular addresses have been published in three volumes. But it is only the scientific man who can appreciate the range and originality of Kelvin's performance. As Shelly is the poet's poet and Velasquez the artist's artist, so Kelvin is the man of science who appeals especially to his fellow-workers. They may criticize what they regard as his limitations, but they are full of admiration for the man and his work. It covers an immense field—elasticity, hydrodynamics, heat, electricity and magnetism, the nature of the ether and the constitution of matter. This is not the place to attempt to describe his experimental work or his far-reaching speculations. A sketch will be found in the tenth volume of this magazine, and among the many obituary notices we may refer especially to one in the issue of *Science* for January 3, by Professor Webster.

It is pleasant to remember that Kelvin three times visited this country. He brought Great Britain and the United States closer together by his contributions to transatlantic telegraphy and to navigation, and his most elaborate mathematical speculations are to be found in the lectures given at the Johns Hopkins University in 1884 and published many years later under the title "Molecular Dynamics and the Wave Theory of Light."

THE CONVOCATION WEEK MEETING AT CHICAGO

There was a notable assemblage of scientific societies and scientific men at the University of Chicago during convocation week. Not hitherto has there been such a meeting west of the Atlantic seaboard. This is gratifying as an indication of the increased readiness of scientific men to cooperate in their organizations, and especially as a demonstration of the great growth of science in the central states. The American Association for the Advancement of Science last met at Chicago forty years ago. It was the seventeenth meeting and the third in size, the attendance being 259, of whom probably less than half were scientific men. Other meetings held so far to the west with the registration have been: 1877, Nashville, 173; 1878, St. Louis, 134; 1883, Minneapolis, 328; 1893, Madison, 290; 1901, Denver, 311; 1903–4, St. Louis, 385; 1905–6, New Orleans, 233.

E. O. Lovett, Ph.D.,
Professor of Astronomy at Princeton University. Retiring Vice-president and Chairman of the Section of Astronomy and Mathematics. President-elect of the Rice Institute.

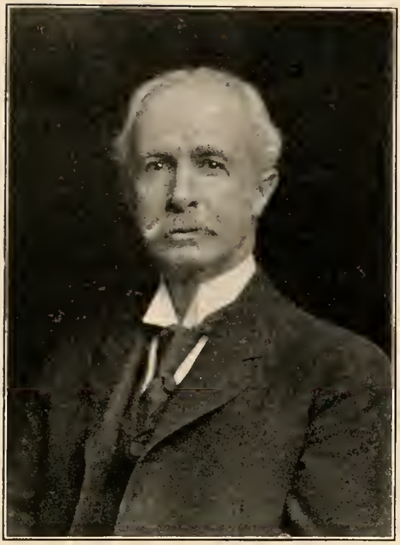
It will be noted that in recent years the association has fulfilled its mission as a national organization by meeting as far west as Denver and as far south as New Orleans. But the registration has been comparatively small. At the present Chicago meeting the registration was 725, and the general secretary estimates that this represents an attendance of scientific men close to two thousand. This is only about twenty per cent. less than at the largest eastern meetings.

The magnitude of the meeting is mainly significant as the most convenient measure of its scientific importance. There were 159 papers on the programs of the American Chemical Society, the American Society of Botanical Chemists and the Chemical Section of the Association. While the chemists are the largest group, the programs of special papers in other sciences were in proportion. There were also many general addresses and less technical sessions. First should be mentioned the address of the retiring president of the association, Dr. W. H. Welch, of the Johns Hopkins University, who traced with characteristic charm and clearness the historical interdependence of medicine and other sciences of nature. The standard set by this address was maintained by the chairmen of the sections and the presidents of the affiliated societies. Among the general discussions should be mentioned that before the American Society of Naturalists on cooperation in biological research, and those before sections of the association on public health, immunity and the teaching of mathematics to students of engineering. The well organized and interesting sessions of the newly organized section of education, with the address of its first chairman, Dr. Elmer E. Brown, United States Commissioner of Education, deserve special mention.

The American Association is becoming increasingly a center for affiliation and organization, the special programs

Dayton C. Miller,
Professor of Physics, Case School of Applied Science. Retiring Vice-president and Chairman of the Section of Physics.

T. C. CHAMBERLAIN, LL D.,
Head Professor of Geology at the University of Chicago and President of the American Association for the Advancement of Science.



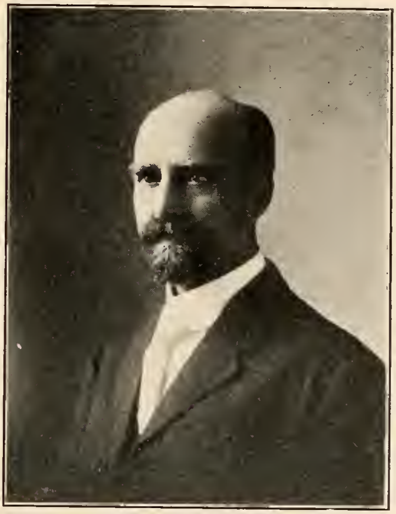
J. P. IDDINGS, Ph.D.,

Professor of Petrology, at the University of Chicago. Retiring Vice-president and Chairman of the Section of Geology and Geography.

CHARLES E. BESSEY, Ph.D.,

Professor of Botany, University of Nebraska. Retiring Vice-president and Chairman of the Section of Botany.

being in large measure delegated to the national scientific societies, while the council, representing both the parent association and the affiliated societies is able to speak with authority in behalf of the science of the whole country. The number and character of the resolutions passed by the council at the Chicago meeting is significant. In response to a letter from the president of the United States a committee was appointed on conservation of the natural resources of the country. Resolutions were passed recommending a research laboratory for tropical dis-



ELMER ELLSWORTH BROWN,

U. S. Commissioner of Education. Retiring Vice-president and Chairman of the Section of Education.

eases at the Isthmus of Panama and a biological survey prior to the migrating of marine animals that will occur when the canal is completed, supporting the committee of one hundred in its efforts to increase the efficiency of the government in dealing with problems of public health, advocating the enlargement of the work of the Bureau of Education, favoring work in seismology by the national government, and in other directions. The association will a year hence commemorate the hundredth anniversary of the birth of Darwin and the fiftieth anniversary of the publication of the "Origin of Species."

The University of Chicago offered admirable facilities for the meetings and provided in every way for the entertainment of members, while the other institutions of the city showed all possible courtesies. The social events closed fittingly with a dinner to commemorate the conferring of the Nobel Prize and the Copley Medal on Professor A. A. Michelson. The University of Chicago was also able to supply a distinguished president for the next meeting. Professor T. C. Chamberlin, one of the world's greatest geologists, will maintain the high traditions of the office, so well represented at the Chicago meeting by Professor E. L. Nichols, of Cornell University. There will be a summer meeting of the association at Hanover, N. H., on the invitation of Dartmouth College, beginning on June 28, and the next convocation week meeting will be held at Baltimore during New Year's week on the invitation of the Johns Hopkins University.

SCIENTIFIC ITEMS

We regret to record the death of Charles Augustus Young, the eminent astronomer. A sketch with a portrait will be found in The Popular Science Monthly for July, 1905.—We further much regret to record the deaths of two other distinguished American men of science: Dr. Nicholas Senn, the surgeon, and Dr. Coleman Sellers, the engineer.—Among foreign men of science the deaths have occurred of M. Janssen, director of the Meuden Astrophysical Observatory, and of Dr. Alphonso Sella, professor of experimental physics at Rome.

The Hayden memorial medal of the Academy of Natural Sciences of Philadelphia has been conferred on Dr. Charles D. Walcott, secretary of the Smithsonian Institution.—Professor Simon Newcomb has been elected a foreign member of the Göttingen Academy of Sciences and Mr. G. K. Gilbert a corresponding member of the Munich Academy of Sciences.—Dr. W. W. Keen, professor of surgery at Jefferson College, has been elected president of the American Philosophical Society, Philadelphia, to succeed Professor Edgar F. Smith, vice-provost of the University of Pennsylvania and professor of chemistry, who declined reelection. —The American Philosophical Society will hold a general meeting on April 23, 24 and 25.

Mr. John D. Rockefeller has added $2,191,000 to his previous gifts to the University of Chicago, making the total amount of these nearly $24,000,000. Of Mr. Rockefeller's recent gift, the sum of two million dollars is for permanent endowment; the sum of $155,000 is to meet the deficit for 1907, and the sum of $36,000 is for miscellaneous purposes.

By the will of the late William George Pearce, Trinity College, Cambridge University, receives about two million dollars. This is one of the largest gifts or bequests ever received by an English university.

THE
POPULAR SCIENCE
MONTHLY

MARCH, 1908

AMERICA'S INTELLECTUAL PRODUCT[1]

By Professor ARTHUR GORDON WEBSTER
CLARK UNIVERSITY

IT may not be out of place for one who is unaccustomed to the constraint of reading from a pulpit to fortify himself with a text. From an excellent source I select the following: "Behold, a sower went forth to sow; and when he sowed, . . . some fell upon stony places, where they had not much earth: and forthwith they sprung up, because they had no deepness of earth: . . . but other fell into good ground, and brought forth fruit, some an hundredfold, some sixtyfold, some thirtyfold." And also: "Ye shall know them by their fruits."

This is an epoch of the superlative. The prosperity of our country is at its highest. Our exports and imports have reached the highest figures of a succession of record-breaking years. The crops are so great that our railroads, of greater extent than those of any other country, congested with traffic, are unable to find cars to transport them, and parts of the country are suffering for such necessities as coal, owing to the plethora of others, such as grain. Business undertakings are greater than ever before in the history of the world, and as a consequence we have merchant princes whose wealth beggars the imagination and makes the rich men of antiquity look poor in comparison. Not only have we greater millionaires, but more of them than any other nation, and our total wealth far exceeds that of any other land in this or any other time. Not only have we rich, but our working classes are more fortunate than others; they are all busily

[1] The following article was given as an address at Clark University on Founder's Day, February 1, 1907, and although some of the statements therein made might now be somewhat modified, it has been deemed best to print it verbatim, and without removing the local allusions, since its application is general, rather than particular.

employed, and wages are unusually high and still going up. So fortunate do we consider ourselves that a great political party, with a complacency that almost compels admiration, taking credit to itself for the conditions that have produced these unprecedented results, presents as its watchword, borrowing an elegant phrase from the gambler, the injunction to "Stand pat," on the assumption that conditions are so near perfection that they can not be improved.

Conditions being as I have described, let us imagine an intelligent traveler from Altruria, or from Mars, coming among us, and let us fancy his observations. "Surely," he will say, falling into the superlative, "this is the greatest country in the world. The easy circumstances of your people have undoubtedly left them time for the enjoyment of art, of literature and of science, and have enabled them to cultivate the love of beauty and of truth as no other nation has done. Your rich men have had the leisure to educate themselves to the highest pitch, to patronize the arts so that your architecture, your paintings and your music surpass all others, and have been able to constitute themselves a leading class whose influence by their writings, their scientific discoveries and their civic devotion has made them an aristocracy such as the world has not seen." I fancy I see a slight shade of embarrassment spread over the face of his cicerone, say in New York or Pittsburg, from which he presently rallies, as he points out to the stranger, "To be sure, speaking of architecture, that office building is the tallest structure in the world, overtopping the cathedral of Cologne, and doubling the height of the pyramids; either of those two railway stations is larger than any other; as for music, every family has an automatically played piano, in these two opera houses sing artists paid salaries higher than anywhere else, mostly Europeans to be sure; in this gallery are the most expensive pictures to be had in Europe, no princely family in Europe being able to resist our offers; as to literature, our newspapers are larger, printed faster, in larger type, and containing more news, unimportant it is true, than any others, and as for science, these dynamos furnish more current than any others in the world. As for the power of our rich men, one of them controls more miles of railway than would go around the earth, which he manages all for the benefit of the public, while others freely give their energies to the management of great public institutions which insure what poor we have against the terrors of old age and death."

But enough of imaginary conversation, and let us examine in all seriousness what are the fruits by which America shall be known. Within the last few years we have frequently heard the exultant statement that the United States is now a world-power. What is a world-power? Is it a nation whose armaments are able to wring from all rivals their richest possessions, their consent to unlimited aggression? What is the power that moves the world to-day? No sooner is the greatest warship of the world, the *Dreadnought*, launched by England, than a still greater one, the *Satsuma*, is launched by Japan. Must we exceed these in order to be a world-power? From the depths of my soul I believe not. What matters it to history how many thousand tons of steel or bales of cotton or bushels of wheat we export to Europe? Is not the question this, how many *ideas* do we export, and is our product commensurate with our material greatness? What care we that Sparta was victorious in the Peloponnesian wars, if she has left to our civilization no reminder of herself, while the ideas produced in Athens will keep her remembered when both her temples and our sky-scrapers shall have crumbled into dust.

Certainly we have some fruits to offer to history. Poetry and philosophy are to-day everywhere somewhat below par, but we have in the one produced Lowell and Whitman, and in the other Emerson, all redolent of the American soil. I do not suppose that I shall be disputed if I express the opinion that we to-day possess no names to be compared with those of Rostand in France, d'Annunzio in Italy, Hauptmann and Sudermann in Germany, Maeterlinck in Belgium, not to speak of Ibsen, but lately gone, from Norway. To be sure, we have novelists, and though Stevenson and Kipling were only sojourners here, we have Howells and James, to say nothing of more ephemeral writers. Still we have in no branch of literature such commanding names as in painting those of Whistler and Sargent, whom we claim as Americans though they spent most of their lives in Europe. The sense of the country for architecture has but recently been aroused, but the enormous progress that has been made in this direction will be admitted by those who remember the exposition buildings of the Centennial Exposition at Philadelphia and compare them with those of the Columbian Exposition at Chicago or the Louisiana Purchase Exposition at St. Louis. We may now find scattered through all parts of the country noble buildings, exemplifying models from Greece, France and Italy, even if we have not been able to originate a national style, unless our tall buildings are to be so considered. In the art of painting we are now able to hold up our heads as a nation, having distinguished exponents of its various branches, most of whom obtained their inspiration in France, if indeed they do not, like the two I have previously named, prefer to live there. Nevertheless the possession of the undisputed preeminence of Sargent among portrait painters and Whistler among etchers may reconcile us to their exile from the land which claims them. In sculpture the same may be said, in a less degree, as in painting, and the possession of St.-Gaudens may reconcile us to his Irish birth and his French name.

But whatever the status of our country in art and literature, it will be said, there is one matter in which we are particularly strong, namely in education. Our common schools are the boast of every patriotic American, many of whom believe that such schools are unknown in other lands; our colleges and universities are in number more than those of any other country, and for our education we pay a greater sum than any other country does or could afford. Education is the one thing of whose value all Americans are convinced, and for which most of them are willing to make sacrifices. Not only do we have the greatest millionaires, as I have remarked, but they give away more money than any others, and education obtains a large share of their benefactions. No other country possesses privately endowed institutions comparable with our great universities, and in none is the generosity of rich men developed to so high a degree, when measured in numbers. It has recently been announced that Mr. Rockefeller has just brought the total of his gifts to the University of Chicago up to the sum of twenty million dollars, while Mr. Carnegie has given the same sum to two institutions of very recent foundation, both bearing his name, and it is to be remembered that in both these cases the sums named constitute but a fraction of the amounts contributed by these great givers to educational purposes. These are but two of the great number of generous contributors to education in our day, and they have been preceded by a long line of others whom we remember with gratitude.

The question now lies near, what are the results of this grand investment in education, in which not only the fathers, but we of to-day, take such an interest? No sensible man to-day asks the question, "Does education pay?" The great question that interests the engineer or the physicist in connection with any apparatus, machine or transformation of energy, is its *efficiency,* that is, the ratio of what comes out to what is put in. If I may be pardoned for introducing a well-worn anecdote, I will remind you of the reply given by the Hebrew capitalist to his wife, interested in family matters, "Isaac, have you noticed how much interest young Mr. Loewenstein is taking in our Rebecca?" "Interest," says Isaac, looking up from his stock report, "Interest—*what per cent.?*" It is precisely this query to which I wish to call your attention to-day—how great is the efficiency of our educational plant, or, in commercial language, what per cent. of dividend does the investment pay? An answer to this may be of interest to future givers, unless indeed they are so permeated by the prodigality of the times that they will give their money in any case, and take their chances of its doing any good. Let us then take a brief survey of the state of learning in the United States. What is the attitude of the public toward learning, and toward the universities and colleges in particular? What influence do these exert on the ideals of the people? What is the intellectual or spiritual product of these numerous and well-endowed institutions, and what aspects of them are most prominent in the eye of the public? At the very outset of this inquiry it is somewhat depressing to note the divergence of opinion among experts as to what education is, and what it is for. Those who have attended meetings of college presidents or educational conventions can but have been impressed with the diametrically opposite views expressed. To be sure, there are a certain number of pet phrases and theories which we often hear repeated, and one sometimes thinks, in reading the proceedings of "Educators" in session, "Plus ça change, plus c'est la même chose." Education must be for life, we hear. Undoubtedly, but what is life? Does it consist in eating three meals a day, sleeping at night, and the next day the same? We hear of education for citizenship. But is it so hard to be a good citizen that these elaborate and costly institutions are necessary to bring it about? I recently heard a gentleman remark with an air of finality, "Of course ninety per cent. of what a young man gets in college comes from the association with other young men." If this is true, it seems to me that there is something wrong with our institutions, and that the same result could be obtained in a far cheaper manner. This view takes little account of the influence on the young of strong and mature men, veterans in the conflict of life, and of the passing on of the garnered experience of the race. The maintenance of faculties, at least on their present scale, would seem to be quite unnecessary from this point of view. Under the old college régime, the students had far more time and opportunity for association with each other than at present. Have we, therefore, advanced in the wrong direction? Considering the prevalence of such views, it seems to me to be worth while to emphasize the fact that a college or university is, in the first place, a nursery of learning; I mean a place where knowledge is not only *inculcated, but is produced.* It would seem absurd to put forward this view, were it not so often lost sight of. The late Sir Walter Besant, in an article in the *Harvard Graduates' Magazine,* remarked upon the fact that at the commencement exercises that he had attended in this country, he heard much of the public services rendered by the graduates, and of their distinguished contributions to citizenship, but he had heard little of the distinguished scholars that the institution had produced, and that it would appear that that was a matter that was not considered of great importance. At similar occasions at Oxford or Cambridge, he stated, much was made of contributions to the world's thought made during the year by the university's sons, in which achievements the *alma mater* took great pride. I believe the same fact has also been noticed by others who attend academic occasions. In this respect the colleges do not differ essentially from the public, which is, to speak plainly, little interested in learning, and knows little of those devoted to it. If the future historian, or the traveler from Altruria, wishing to inform himself of the relation of the public to the colleges, should consult the documents, that is the newspapers, could he help concluding that the main business of the institutions of learning, and the one supported by the public, was the cultivation of athletic sports and contests? Are not our largest colleges chiefly known to the newspaper-reading public through the records of their athletic teams? When we hear the "spirit" of certain institutions spoken of, does it mean anything else than a concentration of all the forces of youth on the task of overcoming athletic rivals? It is, to be sure, an inspiring sight to see these forces concentrated on anything of importance with the determination to overcome difficulties, but does not the importance of the athletic success seem magnified out of all proportion, and is it compatible with that sane view of life which should, above all, be the possession of the educated man? Let us consider the amount of interest in athletics on the basis of the sums expended for it in comparison with other departments of activity. In a recent daily paper I find the budget for athletics at the University of Pennsylvania for the past year to amount to $88,863.85. During the same time fifteen colleges and universities in the State of New York, including Columbia and Cornell, spent on books for their libraries $67,587. This is less by $20,000 than the sum spent for the same purpose by the Brooklyn Public Library. We also find that at a single football game there is taken in in gate-receipts the sum of eighty thousand dollars, a sum, I may say, more than sufficient to run this university and college together for a whole year. What a commentary are these figures on American civilization! I do not grudge the expenditure of money on gymnasiums or whatever is necessary to the development of muscle and the maintenance of health, which is the prime necessity for success in any walk of life, but when I find in the above budget the sum of $29,688 for football, I feel a certain sense of scandal. I am aware that certain cities in the days of the decadence of Rome maintained bands of gladiators for the diversion of the public, but I can not feel that we shall do well by imitating them. I have never been able to reconcile myself to the spending by my own *alma mater* of over one hundred thousand dollars for a stadium, while she alone of all the great universities lacks a worthy library building, and can not find the funds to build it.

It will be said in explanation of the public interest in athletics that this is the field of activity most visible, even if the activity is not the greatest. Let us consider what are the fields of activity of a college or university. Founded at first with the avowed object of educating young men for the Christian ministry, our colleges naturally developed after the model of the English colleges, which, being intended for the education of certain classes in the community, were long dominated by medieval ideas and traditions, and made their main business the teaching of the ancient languages, for, if we include what was then known as "the mathematics" we find it to have been restricted to so much mathematics as was known to the Greeks, as if man's brain had lain dormant since their day. Such was the condition at the beginning of the nineteenth century, and even much later in this country. During this time, however, the modern sciences had arisen, and many of them had obtained a great development, especially mathematics, which, by the invention by Descartes of coordinate geometry, and by Newton and Leibnitz of the Infinitesimal Calculus, had forever emerged from the chrysalis in which the Greeks left it, and had become a thing of marvelous power, fit to display the highest flights of the human intellect. Were these triumphs of mathematics now exhibited to the academic youth? Far from it, they were not even informed that such existed. In fact, we have good reason to doubt whether their existence was known to any one in the country. As far as colleges were concerned, if we consult the diaries of students written a little over one hundred years ago, we find that they were instructed in matters now considered fit for the grammar school. A student at Harvard speaks of running away from recitations and going out to work with a surveyor's compass by way of diversion, but there is no suggestion that he knew anything even of trigonometry, now considered a proper subject for the high school. At the period in question the sciences of physics and chemistry were beginning that marvelous development which has continued to our day. Were the students of seventy years ago made acquainted with the discoveries of Thomas Young and Fresnel in light, of Oersted and Ampère in electricity? We must again return the same negative answer. But come down to the period of forty years ago, when the country was advanced enough to be in daily communication with Europe and to take an interest in intellectual matters, and had by its successful termination of a great civil war put itself in a place of respect among the great nations of the earth. It was then possible, to be sure, to learn a little science in college, but as for the advances that were being daily made in Europe, little enough was known of them. In fact, we must confess that during this whole period we remained in this country in the Rip van Winkle stage with regard to knowledge merely of what was going on in scientific Europe. Did it occur to any of our people that this country had anything to do in connection with this great creative movement of knowledge? That our standing among the nations of the earth was in any way dependent on the production of new knowledge on American soil, and that if we did not expect forever to occupy a position of intellectual mediocrity, it would be necessary to do more than retail what others had produced. Apparently not to any extent. Scholars we had, to be sure, mainly in the direction of history, and some literary men. We had indeed already produced inventors in the mechanical arts, men of wonderful alertness of mind, who gave a character to the national genius, and did much to help us to the industrial supremacy that we to-day possess. But the pursuit of searching into the laws of nature, with the object of advancing the stock of knowledge of the human race, was then hardly thought of. Who had made the great discoveries which were the chief distinction of the nineteenth century? In some cases persons of private means, sometimes physicians, but more and more professors in the universities of Germany, France, England and Italy, and the smaller countries of Europe. In these countries it has always been assumed that the greatest intellectual activity would be found among professors in the universities, who would be expected, as a matter of course, to produce those fruits in the way of new knowledge that would make the glory of the nation. Thus we find Napoleon, reforming everything in France, surrounding himself with a scientific galaxy of the greatest brilliancy, feeling that this, no less than military success, was for the glory of France. Germany, hardly recovered from the effects of the Napoleonic wars, set about founding new universities or strengthening old ones, and their professors were constantly adding to knowledge in every direction. The spirit of work and of research was the characteristic spirit of the German university. Germany was in this way attaining that intellectual primacy that no other nation may to-day dispute her. In the meantime the universities of England were lagging behind the scientific movement, and ours were still well in the rear of them. It was not until after the successful prosecution of the Franco-Prussian war that the appearance of Germany on the stage as a political world-power began to call our attention to the real source of her power, and finally the wave struck us. Young men then began to go to Germany and to drink in inspiration at the fountain whence it flowed so freely. When my colleague, Professor Story, reached Berlin in 1871 he found few Americans, but on my own arrival fifteen years later the stream had swollen to a goodly number, although it had by no means reached its flood. The advent of the hundreds or thousands of young Americans returning from Germany full of the enthusiasm for production, which it is impossible to avoid catching there, began to have a very decided influence on our academic ideals, and our universities opened their eyes to the fact that there was no reason why we, too, should not contribute to the increase of knowledge.

Let me not be misunderstood, nor accused of claiming too much for the influence of Germany. I know that there are to-day personalities potent in the educational world who alternately pooh-pooh and dread the influence of Germany. Although I can not sympathize with them, I am far from maintaining that our liberation from bondage to medievalism began when students began to go to Germany. I do not forget Franklin, whose scientific researches made him a great figure in the great world when it was hardly known what an American was, but I must point out distinctly that Franklin was not only the product of no university, but that he was never a professor in one, so that he constitutes no exception to the condition that I have described. I remember also with pride the discoveries of Joseph Henry, the first secretary of the Smithsonian Institution, whose great discoveries in electricity entitle him to be named with Faraday, and had there been here any appreciation of scientific research or had the means of communication with Europe been greater, and especially had not Faraday made most of the same discoveries in England, Henry would have made his name one for all Americans to cherish as a national glory. It is with feelings of peculiar pleasure that I notice, each spring on my visit to Washington, the statue of Henry in front of the Smithsonian, a welcome change from the bronze man on horseback with cocked hat and sword with which the capital swarms, and a quiet proof that even republics are not totally ungrateful, and that they recognize that there are other kinds of glory than military glory.

It would be impossible to pass over in silence the great influence of Louis Agassiz, coming to Cambridge over fifty years ago, who by his wonderful personality not only encouraged many to take up research as a profession, but also kindled the imagination of the public, and led it to see that science was deserving of respect, and not of the suspicion that it had often encountered on religious grounds. Such was the success of Agassiz that we still hear stories of him that would seem to mark him as the first to succeed in opening the purses of the rich for scientific research. Agassiz did more for science than is possible to many; he left a son who not only rose to the highest level among American scientists in the same line as his father, but, more practical in his applications of science, and equally actuated by the desire to advance science itself, was able to exercise a generosity that, until the time of the present millionaire gifts, made him the largest single contributor to Harvard.

It is frequently supposed that the American public is extremely interested in the results of scientific progress, and so it is, in a certain sense. Certainly we can not accuse it of lack of alertness, when it reads more than any other—in the newspapers. It reads with eager interest, and with implicit credulity accounts of the supposed discoveries of science, taking at equal value the productions of notorious charlatans and those of real investigators. It reads with wonder of the discovery of radium, laying particular weight on its costing millions of dollars an ounce, much as it speaks of Mrs. X's hundred-thousand-dollar tiara, or Raphael's million-dollar Sistine Madonna. With equal interest it reads of the production of energy out of nothing, of communication with the dead, or the discovery of the origin of life. America is, as we know, the favorite resort of new religions, intellectual fads, and isms, ologies and pathies of every sort. As a symptom of the attitude of the public toward science I may mention the fact that the press does not yet consider scientific news to be good business. While every paper of metropolitan standing maintains an expert for literature, for the drama, for music, and many for sport, I know of but three, the New York *Sun*, the *Evening Post*, and the Boston *Transcript*, that retain the services of a regular contributor to acquaint the public with the current achievements of science. I have for years taken one of the great Boston dailies, but I find it almost impossible to find from it who has obtained the Nobel prizes, and I take it as extremely likely that the rest of the public is in the same position, for many had never heard of these prizes until one of them was conferred on the president of the United States. Do not the facts that I have mentioned lead us to the necessary conclusion that on the American field there is no great depth of earth, and point emphatically to the need of both deepening the soil and fertilizing it? When we come to sum up the achievement of this country in science we find ourselves somewhat embarrassed. There are in the dictionary of scientists recently published by Professor Cattell the names of about four thousand men who have been engaged more or less in research, that is, one man in every twenty thousand of the population of the country. Does this look as if the prosecution of science was looked upon as of great national import? Of those who have received the honor here most coveted by scientific men, of election into the National Academy of Sciences, we find ninety, or a little more than one man in each million of the population. Either this body is absurdly limited, or science can hardly be said to be flourishing here. What is the product of these four thousand scientists? I will grant that much of it is of an excellent order, that we have many flourishing scientific societies, and that in many sciences we maintain our own journals which are to be found in every scientific library in the world. But nevertheless it is plain that so far few fundamental discoveries are made here, that we neither discover radium, split up the atom, nor find new gases in the air. The Nobel prizes have not yet crossed the water, nor do they seem particularly likely to in the next few years. In fact we find ourselves in much the same state with regard to science as with art and literature. We have our Sargent and St. Gaudens, our Howells and James, we have also our Michelson and Morley, our Newcomb, Hill and Agassiz, and a good many others of varying degrees of prominence, but not of commanding rank. It seems accordingly pretty evident that our product is as yet hardly what we might justly expect considering the stress we lay on education and the amount of money we spend.

What is to be done in order to change this state of things, and to relieve the United States from the aspersion of mediocrity in intellectual achievement? Is it not our plain duty to urge in season and out of season the importance of research, and to insist upon it as the main concern of every occupant of a university or college position? I put this not only on the ground of duty to our country in order to maintain her position with self-respect among the other nations, but on account of its preeminent importance as a vitalizing and energizing influence on teaching. If the public does not take a great interest in the doings of the colleges and the professors, is it not because of the fact that the professors do not produce that crop of fruit that may fairly be expected of them? How can the public become enthusiastic over professors whom they consider in the light of pedagogues paid to hear the young men say their lessons, and to repeat over to them what they themselves have read in the books of others? Will not that teacher make a far greater impression on the student if he knows that he is continually occupied in work that is his own individual creation and that is increasing the sum of human knowledge? There is no doubt that the absolutely essential quality in a teacher is enthusiasm, without which it is impossible to exert any inspiration. Who is so likely to possess this quality *sine qua non* as the man who is continually occupied in the engrossing task of wringing her secrets from nature, or drawing new conclusions that his powers of reasoning have enabled him to perceive for the first time? I well remember my first impressions on arriving in Germany. After an experience of five years as student and instructor in Cambridge, where it was considered (among the students, for I will not do the professors the injustice of making them responsible) good manners not to be warmly interested in anything in particular, the entrance into a community where every one was tremendously interested in the piece of work on which he was engaged, and was not ashamed to talk of it, where there were persons enough studying the same subject to make discussion attractive, and where, after a morning in the laboratory, one would adjourn to a restaurant and talk shop all through dinner, this was to me a tonic like the effect of a cold bath. I shall never forget the first time I saw the great Helmholtz. In my anxiety to secure a place in his laboratory, I committed the breach of etiquette of calling on him at his house instead of at the laboratory. Ushered into his study, I found him standing at work at his desk, from which he turned and transfixed me with those piercing eyes. Never in my life have I felt so small and insignificant, knowing myself to be in the presence of the greatest scientist alive. During the years that I spent in Berlin, I must acknowledge that the help I received directly from Helmholtz was not great, but we all felt such an unbounded admiration and respect for the great man, such a pride in reading his investigations as they appeared, and trying to understand them, that I would not exchange those memories for any amount of assistance in the preparation of a doctor's dissertation. After spending the four happiest years of my life in this atmosphere, when it came time to return home it was with some misgivings that I began to consider the prospects of the life about to begin. On the steamer returning I fell in with a classmate from whom I learned something of a new institution in which great stress was laid on research, a fact that produced an agreeable stimulus in many others than myself, as I have since learned.

The foundation of the Johns Hopkins University in 1876 marked an epoch in education and in science in this country, for into it President Gilman succeeded in gathering such a body of strong and enthusiastic scholars all permeated by the spirit of research and production as had never been got together in this country. What American physicist does not owe something to the life and work of Rowland, what biologist to that of Brooks? From that remarkable circle of inspiring teachers came one who was to furnish the creative ideas for this Clark University, where the idea of research, of the production of *fruit* as the criterion of vitality, was to be emphasized as had never before been the case in this country. The idea of founding a university without a collegiate department was derided in some quarters. "No students to teach! What do your professors do then?" was the question frequently asked. And yet the prospect was unspeakably alluring to many young men. One of my colleagues tells me of a letter that he received from a friend who declared that on reading the first announcement of Clark University he felt like selling all he had and going there. This I believe was the feeling of many others. I was not so fortunate as to be here the first year, but I have had described to me by colleagues the exhilaration of the start in the race, in the company of a band of leaders, mostly young, but already eminent, and every one imbued with the determination to do all that in him lay toward the increase of knowledge and the glory of his country.

Of the history of the university it is not for me to speak. My remarks are not intended to be of local, but of general, application. My main contention is of the indispensability of research, by all teachers, not only in universities, as a means of vivification and fructification. It is hardly necessary to speak of the necessity to the community of research, on account of its practical applications. Of this the public is becoming decidedly sensible. To say nothing of those great practical utilities, the telegraph and the telephone, the application of steam and electricity in the production and transmission of power, the conquests of biological science in its applications to medicine and the preservation of the public health, are matters of common knowledge. The disappearance of the plagues with which the cities of Europe were so frequently scourged, of the ravages of smallpox so prevalent one hundred and fifty years ago that one person in every three or four was marked with it, and finally the control of yellow fever and malaria, speak volumes in favor of medical research. Who is doing the medical research of the world? In this country the statement is made that out of about one hundred thousand physicians not over five hundred are engaged in research. Fortunately the Germans are at this too, so that every physician has the ambition to study at some period in Germany, and find out all he can of the newest methods of practise and discovery.

The effect of research on the industries of a country is well known. One of the most celebrated applications of chemistry was the creation of the aniline dyes. This discovery, made in England, bore its greatest fruits in Germany, and at the recent celebration in London of the jubilee of the discovery of the aniline colors in honor of Sir William Perkin, one of the speakers said that it was a painful fact that although the English had the discoverer the Germans had the factories. In fact, the Germans not only make the dyes, but the greater part of all the fine chemicals for the world. Every one of these great German factories employs scores of chemists, each with a doctor's degree from a university, not only for the purpose of superintending the manufacture, but for the prosecution of research and the development of new processes and products.

In the commercial race of to-day, England has lost that preeminence that she once had, and is extremely nervous with regard to the competition of the United States and Germany. If we compare the methods of the latter two countries, I believe we shall find a decided difference. In this country success has been achieved by the application of business acumen, in finding out how to save cost by the concentration of huge amounts of business under one management, and by production on a large scale. When it comes to improving the quality of the product, we are not so successful. As a familiar example take the steel manufacture, where we have passed England in the quantity of the steel we manufacture, but if steel is wanted of the finest sort for razors the greatest part of it still comes from England or Germany. The principles of the manufacture of steel are still largely a mystery, and the development of the method that seems to give us the most information on this subject, that of metallography, or the study of metallic alloys under the microscope, has been developed to a great extent in Germany and France. We see the same tendency to concentration of talent on the business end in the management of our railroads. Can any one doubt that these are now managed with far less energy than twenty years ago? Our railroads are now in the hands of financial magnates, and the attempt to do more business takes precedence of everything else. The great increase in the number of fearful accidents bids fair to open the eyes of our good-natured public to this tendency.

I believe I am justified in the generalization that the American talent has made its success rather in business organization and in invention that did not require great learning than in those lines that require deep thinking and solid study. This is the line characteristic of Germany. For instance, we build great steam engines, but it remains a solemn fact that the finest engines are to-day built in the Swiss town of Winterthur, by the firm of Sulzer Brothers. At the Paris Exposition, in 1900, one did not need to be a great expert to perceive that American engines played but a small part there, and that in originality of design and perfection of construction, those of Switzerland, Germany and Belgium were more worthy of consideration. The notion that we are always ahead in mechanical matters receives several rude shocks on careful examination. Some years ago when the power of Niagara was to be developed on a grand scale, it was determined to install turbines of five thousand horse-power each, larger than had ever been built. For the development of this plant the best talent in the world was obtained, and the dynamos were finally built after the combined suggestions of several American and English engineers. The turbines, on the contrary, were built after designs by a firm in Geneva. And yet this is the country of great rivers and water-powers, and at Holyoke turbines of all sorts have been built and tested for years. The reason that the Swiss were appealed to was that they had made such a study of the theory as well as the practise of turbines that they were prepared to design a turbine of any magnitude. As another example we may take the case of the most important subject now before the engineer in the steam turbine. It is true that there is now on the American market one successful American turbine, but it was brought out years after the Parsons turbine in England, and the de Laval in Sweden, and any treatise on the subject now bristles with the names of German, French and Swiss turbines. As an example of the German *versus* the English method, if we open one of the two or three English books on the steam turbine we shall find a very little theory, some specifications and a large number of examples of turbines built by various makers. Opening the chief German treatise, a huge volume by a professor in the Polytechnic in Zurich, we find at first a treatise on the thermodynamics of steam, then applications to the flow of steam through nozzles, then the mathematical theory of stresses in rapidly rotating bodies, finally, the application of these principles to the design of turbines, and then a thorough and methodical description of the principal existing types. Hardly, if at all, less important than the steam turbine is the gas engine, which seems for a long time to have been treated almost as a joke by American engineers, while in Germany it has reached an efficiency far exceeding that of the steam engine and has been built in sizes up to four thousand horse-power. The effect of this indifference in this country was to put us far in the rear of even France in the development of the automobile, although this was a country where the wealth necessary for the pursuit of the automobile craze was present in great abundance. In spite of the number of manufactories of automobiles in this country, I am informed that the Fiat Company of Turin is occupied for the next two years with American orders, the result of the success of its machines in international races everywhere.

I will conclude my practical examples with one more contrast. A year ago I visited a great optical plant in this country. There I saw in one room thousands of lenses for spectacles being ground almost without attention. During the day I saw *one* man who seemed to me to know anything about optics. The business was in the hands of the original founder and his sons. I supposed that the latter, having grown up in the enjoyment of wealth, would have been given the best education possible to train them for their business, and possibly sent to Europe to learn methods there. Great was my astonishment to learn that the gentlemen had not even been at college. In the city of Jena is one of the most remarkable and successful industrial plants in the world. The Carl Zeiss works are known to every worker with the microscope, to every physicist, to every photographer in the world, for here are produced those wonderful lenses that make photomicrography and the more wonderful achievements of instantaneous photography possible. The history of the Zeiss works is as interesting as its products. Fifty years ago Zeiss, a small optician, wishing to get help in improving his microscopes, consulted Professor Abbe, the physicist at the University of Jena. The latter, applying his mathematical knowledge, so improved the efficiency of the microscopes that Zeiss invited him to join forces. Becoming interested in the subject, Abbe resigned his professorship and became the scientific partner. Taking up the theory of optical instruments in general, he completely remodeled it, bringing out points never appreciated before, and inventing new lenses that were beyond competition. At the death of Zeiss, his son not having a taste for the business, Abbe was able to become sole proprietor, and at his death two years ago, full of success and lamented by scientists everywhere, he created of the business a Stift, or foundation, for the benefit of every one employed in the works. This is managed by a board composed of the scientific directors of the different branches of the business, the whole constituting a magnificent monument to German science and cooperation.

If the view that I have taken is correct, the practical question presents itself, what has been done by the colleges and universities in this country to provide for research? I should like to ask all the trustees and governing boards of the institutions of the country the question: Gentlemen, what is your policy—*have you any*—do you believe in research—if so, what provision have you made for it? Do you believe that you have any duty to the nation in this matter? Who, in your expectation, is to do the amount of research necessary to constitute us a world-power in the intellectual sense? Do you realize that the prosecution of research is a very engrossing pursuit, consuming great amounts of time, and not to be carried on in those leavings of moments when the tried teacher has finished his day's task of instruction? That it is also a very expensive process, requiring elaborate laboratories fitted with the ever-changing apparatus quite distinct from the stereotyped stock in trade necessary for the imparting of first principles to the tyro in science? Of the forty million dollars now spent annually in the United States on colleges and universities, what proportion now goes for the provision for research? This it is impossible to tell, but we find that in comparison with the hundred thousand students in our colleges there are only seven thousand graduate students. Of these by far the greater proportion are not to be counted in the research class, but are preparing to be routine teachers of a somewhat superior grade to those who go immediately from undergraduate colleges. These graduate students are largely being taught by professors whose main duties are in undergraduate teaching, and even in our largest and richest institutions the complaint is made that it is impossible for the graduate student to secure any considerable attention from the professor. In many cases expensive laboratories are erected with little or no provision for buying books. I know of but two physical laboratories in this country that have an endowment to be devoted to the fostering of research, the Jefferson Laboratory at Harvard and the Phœnix Laboratories at Columbia.

Fellowships are, to be sure, provided, but not nearly enough. For it is a strange fact that the sons of the rich seldom or never in this country take up learning as a profession, and that most of our serious students have exhausted their means in the four years of college. In a family where there are several children, it is a serious matter to provide a college education for all, to say nothing of the extra three years of graduate work, and the ideas that I have been advocating are so little familiar to the public that many fathers do not understand what more their sons need when provided with a college training. It is useless to make a comparison with the professional studies of law and medicine—these are frankly bread-studies, while it should be expressly understood that the pursuit of pure science has no rewards of a monetary nature. It must be carried on by those who love it and feel called to it, and are willing to make sacrifices for it, but they need not be expected to go without food and warmth, as we often find such students doing. The national government provides richly for the education of those who are to devote their lives to her defense; is there any less reason for providing for those who are to make her intellectually great? Be assured, intending benefactors, that your money will not be wasted by the devotees of science. Of wasting money there are many ways, but not this. Some time ago I stood on a hill above the campus of a large and rapidly growing university, as it is called. At my feet I counted thirteen buildings completed and in process of erection, those of the latter category representing at a crude guess over half a million of dollars, to say nothing of the vast hole into which a third of a million had been poured to make a Roman holiday, a stadium rivaling Harvard's. Meeting a professor, I fell into conversation with him, and he began to describe to me the needs and resources of the institution, and with pride informed me that the endowment was—about two thirds of the endowment of Clark University and College together. When I thought of our three plain and modest buildings I could not but feel that something was wrong, here or there, and I could not avoid the conclusion that what was spread over such a large surface must be rather thin. Knowing as I did the pitifully small salaries paid the professors in that institution and the feeling cherished by most of them toward their president, a highly successful autocrat of the genus hustler, I did not feel that I had cause to envy the university of X. There are no fellowships there, though there are laboratories, and those valiant souls among the professors who do research do so at the risk of their lives. To secure a position there one is not asked, What have you accomplished? but, What is your denomination? Is this a picture of the typical American university? I sincerely hope not. And yet I fear that the picture is not unfamiliar. Certainly it does not remind us in the least of a picture of a university in Germany or France. A friend of mine, a distinguished professor of mathematics in the University of Paris, has as his regular duties the delivery of two lectures a week for one semester, that is, during four of five months of the year. The rest of his time he has for research. The result is that he is one of the two or three of the world's greatest mathematicians. For the amount of work that I have mentioned he receives what until last year was a full professor's salary at Harvard, the largest, with two exceptions, of any in the United States. And yet France is a small country, not rich in comparison with us, and with a national debt six times as great as ours. But France has long been a civilized country, and Paris is proud to call herself "la ville Lumière." At the University of Berlin, Professor van't Hoff, the great physical chemist, was called from his native Holland to occupy a chair of research, in which he is totally freed from the obligation to lecture. Can we not consider the possibility of something of this sort in this country?

During the last few years several institutions have been founded for the sole purpose of the promotion of research, most notably the Carnegie Institution of Washington and the Rockefeller Institute of Medical Research in New York. These noble foundations may be expected to produce great results, but they do not relieve the universities from the duty of providing for research themselves, for research can be much more efficiently carried on in connection with teaching, and it is far more easy to obtain the persons who are to do the work in the universities than elsewhere. The scientist who does not have the inspiration of frequent contact with young and active minds of students is likely to become self-absorbed, one-sided and dried up. It is to be noticed that I have made this plea for research largely on the basis of its effect on teaching, and of inspiration of the students and of the community.

What then, my colleagues of university and college, is our duty? First of all, by our lives and precepts to teach our students that the prime object of the educated man is not to make a living. Is not the life more than meat, and the body than raiment? It is ours to hold up the sacred torch, and to radiate upon the community those ideals which it is strangely in danger of forgetting. It is for us to enrich the American soil, and cause it to bring forth imperishable fruit. And by word and deed to remind the young men with whom we come in contact that life is neither pleasure nor pain, but serious business.

THE GRAIN OF TRUTH IN THE BUSHEL OF CHRISTIAN SCIENCE CHAFF

BY CHARLES CLARENCE BATCHELDER

"WHERE there is smoke, there must be some fire," is a proverb which may justly be applied to the claims made by Christian Science, for it is hardly fair to a large number of educated men and women to jeer at them as the victims of the absurd delusion that they have been cured of non-existent maladies. Not only can they produce well attested cases of undisputed cures of distinct diseases, without the use of medicines, but similar results occasionally occur at Lourdes and elsewhere, and, in fact, have taken place in unbroken succession throughout the centuries ever since the Temple Cures of Ancient Egypt. Though the facts are too well established to be denied, we may yet question the explanations they give of the cause and method, especially when we find that the Pagan idolatry of the priests of Ammon-Ra produced the same effect as the Pantheistic philosophy which Dr. Quimby and Mrs. Eddy adapted from Hindu sources. For though the charge of Pantheism is violently repudiated, it is even more authoritatively affirmed by the statement "God is All, and All is God."

Now while the philosophy is not convincing to the ordinary reasoning mind, a study of the methods of Christian Science can not fail to command admiration, not only on account of the efficient financial management, but also for the clever use of the most effective methods of mental healing. The fact that these procedures were discovered empirically does not distinguish them from the systems of the recognized medical schools, for the uses of most drugs were found in the same way.

It is also not just to accuse the "healers" of being quacks and charlatans, for, though there may be exceptions, it seems well established that sincerity on the part of the operator is usually essential to produce that conviction in the patient which is absolutely requisite for all cures of this nature in every age and time. In other words, the christian scientists are perfectly right in saying that "faith," conviction, belief, are necessary to produce the desired result, and that doubt in the patient, or among those present, is likely to prevent success. The reasons for this will be apparent later.

The opponents of this system affirm that most of the diseases in question are only imaginary, and do not really exist. Though we should grant this at the start, it would not alter the situation much, for imaginary diseases are often as "afflictive" to the sufferer, and more annoying and expensive to the family, than actual ailments, and a debt of gratitude is due to any method of removing them.

The next objection is that the patients would have recovered anyway if let alone. Suppose this is also conceded; the position is unchanged, for the chances are that the disorder would not have been left to the curative processes of nature, but would have been dosed with various poisonous patent medicines, with dangerous results. Here christian science is beneficial by preventing interference. But, after all, is this true, especially of chronic cases? We may well ask why, if nature alone was able to cure the case, it remained unbenefited for years, but quickly recovered as soon as mental healing gave its assistance.

The unexplained instances are jauntily disposed of by attributing them to "suggestion," but giving a thing a name is not solving the problem, and, while there are reams in the text-books upon the effects of suggestion, few seem to attempt to say exactly what it is or how it acts.

The whole subject of mental therapeutics is so discredited that the medical profession hesitates to treat it, but, really, few fields will more quickly repay the application of modern scientific methods. Light even appears in the dark maze as soon as we begin to classify the more reliable cures, as distinguished from those not sufficiently verified. The great majority are disorders of the nervous system, including under this head certain functional affections, and many more are dependent, directly or indirectly, upon morbid conditions of the circulatory system.

Mental healing has not yet demonstrated its power to cure diseases caused by microorganisms, like malaria, pneumonia, diphtheria, yellow fever and many others, and its adherents admit that it is not effective in surgical cases or those where there has been an actual destruction of the tissues. Christian scientists are often taunted by their friends with being unable to cure common colds (caused by bacteria), and with going to the dentist, and with reason, for both these are beyond their powers. They would lose nothing, and would allay much hostility, if they would frankly admit that, for the present at least, these complaints are beyond their scope, and would confine themselves to more successful fields, instead of claiming that they are able to "demonstrate" over cancer and smallpox.

The community has a right to protect itself, and should take measures to prevent individuals from endangering themselves and their neighbors by refusing medical aid in even the minor contagious and infectious maladies. It is somewhat surprising that the able leaders of this movement have not made some attempt toward a solution of this difficulty, which is the cause of much of the current enmity. They must certainly realize their own limitations, and should be clever enough to devise some edict on the subject which would attain its object without impairing the faith of their adherents.

The subject of nervous disorders is so complex that it seems at first hopeless, but the approach by the way of maladies of the circulation is more encouraging, though less traveled. One clue to this labyrinth was discovered many years ago while some young persons were under treatment for excessive blushing, which took place to such an extent, whenever they were addressed suddenly, as to be a source of great annoyance.

The first suggestion was to think of something terrifying whenever the feeling of reddening took place, upon the theory that terror tended to produce pallor, and would thus neutralize the blushing. This was occasionally successful, but it was always difficult to hold a vivid idea of fright, and the repetition of the idea robbed it of its effect, while the stock of new thoughts of this nature soon became exhausted.

The next step was for the patient to hold firmly the idea that he was not going to blush, and to refuse to believe that he was, even if he felt the warmth in his ears. He must *know* that he could not blush, and that he was not blushing. This worked now and then, but the patient naturally found some difficulty in believing that he was not blushing, when he could feel that he was, so the process was only useful when it was started well in advance of the tendency to redden. Here we have an exact parallel to the Christian Science doctrine, "Deny error! Evil and disease are non-existent!" No matter what the facts are, ignore them, and hold firm to the *ideal* that you desire. We see here a universal principle, the ideal must be made real, in spite of all obstacles. Now we may laugh at this system all we wish, but we shall in the end be obliged to admit that in every age it has achieved the wished-for results in minds of a certain class. It has a real scientific basis, however, as will be made clear later, but has the fatal defect of being inapplicable in many cases, because of its conflict with common sense.

Decided progress was made when the patient found that the flush would vanish if he said to himself firmly, "I know that I can stop blushing if I want to, and I will." This was only attained as the result of patient effort, assisted by strong auto-suggestion, by faith in the operator caused by the previous successes, and, as was learned in later cases, by incipient voluntary control of the arteries of the face. Great self-confidence on the part of the operator was required, together with considerable talk about "will power," "self mastery," etc.

Those who have read the books on mental healing will see that the three processes here mentioned—counterbalancing one emotion with another, denying the existence of the objectionable phenomena, and assertion of self-mastery—combined with belief in the process—and in the operator, form a large part, if not all, of the various systems, when stripped of unessential details.

The subject proving interesting, more scientific methods were adopted. The best results were attained in subsequent cases, where the subjects were intelligent, by dropping all indirect methods and by simply explaining to the patient that the walls of the capillaries and small arteries of the face, like all others in the body, are composed of circular muscular fibers under the control of special nerves. If the latter are stimulated in a certain manner, they allow the muscle rings to expand, thus increasing the size of the tubes, and allowing more blood to reach the skin, which causes blushing. If these nerves are stimulated in another manner, the rings contract, the bore of the tubes diminishes, the blood supply is cut off, like the stream of water when a garden hose is stepped on, and pallor results. Under normal conditions, these nerves are stimulated in both ways automatically, but by persistent effort it is quite possible to acquire the art of stimulating them at will either way, just as some people learn how to cry at will, instead of being dependent upon saddening emotions.

Here we have a truth of great importance, which is the foundation of all that follows. The action of the organs of the body is quite clearly influenced by mental states, such as fright, embarrassment, sadness, etc. We can cause at will the same effect, which usually only takes place involuntarily, by producing a mental image of an emotional state, by denying the existence of an existing state, or by acquiring the power to give the same kind of stimulus that mental emotions produce without the actual presence of any emotion. The feeling called "faith" is one of the strongest emotional stimuli, and is so powerful that it produces its result, even masking other emotions. The belief firmly held that we are about to cry, even where there is no cause of sadness present, will very often elicit real tears.

If this principle is firmly grasped, logical progress is rapid. An inflammation of any kind is evidently merely an excess of blood supply to the affected part—a sort of local blushing. The converse is an under supply, which starves the cells by failing to provide sufficient nutriment to them, and also poisons them by not removing rapidly enough the lactic, uric, and carbonic acids which are the waste products of all cell activities; for, as we know, the blood resembles those brooks which flow through oriental villages, serving both as sewers and as water supplies for all domestic purposes. The blood, in addition, transports the food assimilated by the digestive organs, the oxygen absorbed by the lungs, and the fluids secreted by the various glands.

Clearly, if we can control the blood supply to the various organs, many problems of disease are mastered. There is, however, one slight difficulty; though we can in a measure control some local nerves, most of those regulating the circulation are beyond the province of our wills. It seems as if nature were willing to trust us with minor matters like motion, but preferred to attend herself to subjects of real importance like digestion and circulation, while we are forced to conceal our humiliation by saying in a learned manner that "assimilation and circulation are functions of the sympathetic nervous system, not of the higher centers!"

Are we balked? Well, not necessarily! If the highway is blocked, there are yet the by-paths of attention and incomplete motion. While most of us are unable to control our blood supplies by a direct effort of the will, all of us can do it indirectly to some extent. Have we been reasoning in a circle, and are we still upon mere hypothetical ground with the mental healers? Not a bit of it! We here emerge from the perplexities of theory and stand upon the firm foundation of instrumental measurements, owing to the labors of a number of investigators, prominent among whom are Dr. Wm. G. Anderson, director of the Yale Gymnasium, and Dr. Angelo Mosso, of Turin.

Dr. Anderson places a student upon a low, legless table, about the size of the body, so delicately balanced that a breath will make it move, and outlines his figure so that he can resume his position after leaving the "muscle bed" temporarily. Now every exertion, mental or physical, means that more blood must be supplied to the active part, thus increasing its weight, while as the amount of blood in the body is limited, the excess must be taken from some other organ, thus decreasing the weight of the latter. If the man on the bed rises and dances a jig, when he resumes his place upon the balanced bed, his feet will sink, and his head ascend correspondingly.

Now this is nothing startling, as we all know that a member if exercised, will grow at the expense of idle organs, which tend to atrophy from disuse. Now it seems as if we had wandered from the subject of the mind, but we shall soon see that even here the mind is an indispensable factor. Curiously enough, if the man does not leave the bed at all, but merely *thinks* of dancing a jig, simply mentally going through the incomplete motions, but taking care not to move a muscle, the delicately balanced bed will sink at the foot almost as much as if the exercise had actually been performed.

Now it is clear why the Christian Scientists say to a person troubled with cold feet "Hold the thought that your feet are warm! Deny the 'claim' that they are cold"! It is reasonable to suppose that the feet of one of the mental believers would sink upon the muscle bed just as rapidly as those of the mental jig dancer, though we can not give the statistics, as unfortunately it seems extremely difficult to persuade the disciples of Mrs. Eddy to lend themselves to investigations of this sort.

We can even go a step further with the utmost confidence, and say that simple concentration of the attention upon a given part will increase the blood supply. This is capable of experimental verification, for very many people can cause the backs of their hands to redden perceptibly by fixing the attention upon one spot for some time, without the thought of desiring a flush, though that idea usually hastens the process.

This furnishes us a key to some obstinate chronic diseases, where there is no destruction of the tissue, but where an unwholesome condition has resulted from an oversupply of blood caused by undue fixation of the attention upon the part, a permanent blush, so to speak. As the health of the body depends upon the preservation of a normal blood supply, modified by the demands made by the activities of the different organs, we see that an organ constantly oversupplied becomes diseased, like a man who habitually overeats, while this oversupply must be taken from the share of some other portion, which consequently starves. If this is so, it is evident that a cure will follow when the unwholesome attention is discontinued. This shows why the Christian Scientists say "Deny error. If your 'mortal mind' has a claim that an organ is diseased, stop thinking about it. Hold the thought that it is completely well, that you are perfect." This whole line of thought is well conceived, and tends toward mental poise and bodily well-being, for those who are able to believe the tenets.

Having secured some clear ideas about the physiological reasons for some of the Christian Science methods, we are ready for the more difficult aspect of the subject, that of nervous disorders. Every practising physician is confronted with a class of cases in which there does not seem to be an adequate cause for the symptoms, and which are roughly classified under the head of hysterical affections. They include paralysis of various organs, stiffness of the limbs, pain and swelling in the joints, pain in the head and spine, perversions of sensation, overirritability of various functions, and a host of Protean symptoms. The sufferers suffer actual pain, and often very serious inconvenience, but the most careful medical treatment seems unsuccessful. The limits of this article will not permit a discussion of this subject, but it suffices to say that to all intents and purposes the maladies are real, even though they exist only in the imagination. They seem akin to "fixed ideas," and "pain habits," as well as to that phenomenon called the "balky will" frequently met with in childhood, where a child refuses to obey, and then holds the idea so firmly that it is physically and mentally impossible for him to yield. We have all seen it in balky horses which refuse to move until their attention is distracted by a lump of sugar, blowing into the ear, or putting a pinching instrument upon the lip, which succeed where a severe beating only increases the obstinate immobility. Many cases of such fixed ideas are on record, which have been cured by fright. One old doctor was in the habit of curing bedridden patients by letting mice loose on their beds, until they ran shrieking from the room, forgetting all about their ailments.

In a recent case, the husband was sent for the physician, leaving the patient alone in the house. The telephone rang so continuously that she rose and answered it, and was so absorbed in scolding him for not returning in time to receive the call that she forgot that she was out of bed for the first time in years. One man who had a most severe case of asthma, which had caused him the most serious discomfort, was completely cured by the fright of the Kingston earthquake, and has had no relapse, though forced to live under conditions of considerable hardship. This is vouched for by the writer out of his own experience.

Now, while cases of this nature are very refractory to drugs and other medical treatment, they yield with surprising readiness to mental therapeutics. The attention of the patient is distracted, a desire for cure is firmly implanted, interest is excited, and all the conditions are made favorable. The process is not dissimilar from that of stimulating the motion of balky horses with lumps of sugar. The fact that there is no real disease evidently accounts for the failure of the skilled physician.

The successes of Christian Science are largely in these cases, which are principally found among women of the middle and upper classes, who live luxurious, self-indulgent lives, are over-fed, under-exercised, have no occupations or absorbing interests in life, and concentrate their attention upon themselves and their ailments. We are not surprised to find that converts belong very largely to this class, or to learn that many relatives bless any belief that will turn a nervous, sickly, complaining invalid into a cheerful, though perhaps a bit too superior and self-complacent member of society.

A very large percentage of all the cures of all systems of medical treatment without the use of drugs may safely be classed under some of the heads which we have already discussed. It is not unreasonable to group with mental healing many methods more generally accepted by the community, such as "high dilutionist" homeopathy, osteopathy, massage, electricity, water and bath cures, and even allopathy, which, as every physician knows, habitually employs "bread pills" and other similar methods of influencing the minds of the patients.

Making all allowances, however, there are a number of cases of genuine cures, as the result of mental treatment, of serious diseases, which have defied all regular medical processes. The discouragingly dry way of classification will be again most helpful here, as it shows us that these cases are mostly of "functional disorders"—when the organs of the body fail to perform their proper work. It is clearly impossible that any cell in the body should work at high pressure all the time, for adequate rest is essential to all living matter; further, it would be wasteful for secretions to be made when they were not needed, and nature abhors waste, while useless secretions would tend to produce sickness. It is one of the duties of the sympathetic nervous system to stimulate the activities of each organ at the proper time, and also to stop the process when no longer needed. It consists of a double chain of masses of nervous tissue, called ganglia, lying inside and on both sides of the spinal column, connected with each other by nerves, and also with great networks of nerves called plexuses, which govern the heart, blood vessels, intestines, liver, lungs and other organs. The spinal ganglia receive branches from the spinal nerves, which bring them into relation with the cerebellum and brain. The mechanism works reflexly, without the interference of the will. If, for instance, we ascend a mountain where the air is rarer, the lungs work more rapidly, as the result of more frequent stimuli from the sympathetic, thus taking enough more air to counterbalance the deficiency of oxygen. The presence of waste in the circulation stimulates the kidneys, a high temperature excites the perspiration, and the proper conditions cause the other organs to act. The exciting cause in the organ, whatever it may happen to be, sends an impulse up to the reflex centers, which in turn send an order down to the organs to get to work until commanded to stop. If by any means we can send a similar impulse up to the reflex centers without the presence of the usual exciting cause—a false alarm, so to speak—we shall get the regular result. It is also probable that the reflex centers can be made to give the regular orders to start work, not in the customary way by a message sent up to it from the organ, but by direct command of the lower parts of the brain, though not immediately by the cerebrum, or thinking portion. The functions of the sympathetic system are modified by the two pneumogastric nerves which start in the head and extend to the digestive organs, lungs, heart, liver, stomach and other organs.

It will, perhaps, be clearer to select one organ as a type of functional disorder, and follow the process closely, bearing in mind that these remarks do not apply at all to cases where there has been an alteration in structure, as these are not susceptible to mental healing. We will choose the stomach, the most abused organ, as it is defenseless against the acts of the will in putting into it all kinds of injurious substances. It takes its revenge, however, for ill-treatment, not only by causing pain in its own vicinity, but by instigating pain in the chest, dizziness, sleeplessness, headache, black specks and other disturbances of sight, palpitation of the heart, cold hands and feet, general indisposition—called "that tired feeling"—irritability, melancholia, bilious attacks, and other affections. It is interesting to note that if a disordered stomach can be relieved by mental therapeutics, all these symptoms can also be cured by the same means, to the great glory of the healer.

Now the stomach is a patient thing, more patient even than a donkey, but if ill treated too long, it will rebel—go on strike—and decline to handle "non-union materials" in the shape of improper or badly cooked food. Overeating, bolting, insufficient chewing, irregular meals, over-indulgence in alcohol, tea, coffee and tobacco, are, also, apt to produce that prevalent American disease—dyspepsia. The usual factor is a change in the gastric juices, which may be deficient in quantity, or may contain too much or too little acid or pepsin. Sometimes, however, the natural movements of the stomach become irregular, and the food is either hurried too soon into the intestines in a half dissolved condition, or, more frequently, retained too long in an undigested state to ferment and cause pain, gas and vomiting.

Now improper conditions of both the gastric juices and the movements result from a failure of the stimuli of the nervous system. The messages sent from the mucous membrane lining the stomach to the reflex centers stating that food is awaiting digestion may not reach the proper destination, owing to unnatural conditions of the nerves or ganglia; the reflex centers may not give the proper orders; the return nerves may fail to transmit; or the cells of the lining membrane may decline to obey orders. To use the simile of an electric bell—the push button may be broken; the wires disconnected or cut; the batteries may be used up; or the tongue of the bell may be loose.

Such failures of the nervous system are usually the result of overwork of some kind; it is simply tired out, and insists upon rest. The fatigue may be direct, from overeating or improper food, or it may come from general exhaustion from dissipation, worry or mental or physical overexertion. In many cases, simple rest, with freedom from worry and overwork, is sufficient to work a cure. Drugs often actually delay recovery, and we do not really know just why bismuth, rhubarb, nux vomica, gentian, or the newer proprietary and synthetic remedies should assist nature, though we have concluded for empiric reasons that they do. Mental healing certainly gives the nervous system a chance to recuperate undisturbed, and hence is often better than any other treatment. Often, nevertheless, rest is not enough. The rested nerves are still obstinate, and refuse to send the needed orders, resembling balky horses which must be coaxed with sugar. In these instances, also, mental methods will often start the proper reactions when everything else has failed.

Some experiments performed on dogs whose stomachs were kept open for observation will, perhaps, make the situation more clear. If a dog was allowed to eat meat in the usual way, its presence in the stomach caused the reflex centers to send orders to the gastric cells to commence secretion. The mere irritation caused by the presence of objects in the stomach was not enough, for the introduction of indigestible substances, or rubbing the lining with sand, or a glass rod, produced no gastric juice. Meat introduced directly from the outside, not through the mouth, still stimulated the juices. Thus it seemed to be purely a reflex performance—the ganglia seemed to say "you press the right button, we do the rest," the mind seemed to be unnecessary. Nevertheless, if the dog was allowed to swallow the meat, which was removed through a slit in the throat, and not permitted to enter the stomach, gastric juice was as cheerfully secreted as usual. This was puzzling enough, but worse was in store, for if the dog smelled and saw the meat, without even biting it, gastric juice was formed in larger amounts than if the meat were put into the stomach without the knowledge of the dog. Plainly, reflex action here played no part, and mental conditions of anticipation, pure *emotion* in fact, occupied the whole stage.

In other words, the stomach may be controlled in two ways, either mechanically by contact with food, or mentally by the production of emotions. If one fails, the other is still available. If food does not produce gastric juice, the proper mental states may be made to supply the deficiency. The problem of mental healing is here made absolutely clear; we can no longer deny that it is possible. The only difficulty is the method of production of the proper mental and emotional states. This is the most important and fascinating aspect of the subject, but space forbids its discussion in this place, as it leads into the realm of hypnotism, subliminal consciousness, suggestion and double personality. The experimenters were unfortunately unable to obtain data about the mental conditions of the dog, and thus we can not state what the results would have been upon its stomach of the memory of past feasts, the hope of future ones, or the belief or dream that there was meat in the stomach. We must wait for a satisfactory knowledge of the whole subject until some person shall appear with an opening into his stomach, like Alexis St. Martin, who, to our intense regret, died too soon to demonstrate the facts of christian science.

Not only is the stomach largely influenced by mental states, but we all know that joy, sorrow, anger and other emotions cause that extremely rapid and violent action of the heart that we call palpitation, while fright stops its action, through the pneumogastric, so that fainting occurs, or even death. Rage and other mental conditions sometimes intensify the action of the liver enough to bring about jaundice, while many public speakers and soldiers know that fright causes perspiration and stimulates the action of the kidneys. In short, there are instances too numerous to mention of the effect of mental states upon the organs of the body, and the facts may be considered as established.

While the proper mental states tend to stimulate the nervous system, and restore normal conditions, anger, worry, fear and doubt tend to lower the tone of the nervous system and check the functions. It has been conclusively established by observation that favorable results from mental methods are practically impossible unless the patient has confidence; he must *believe* that the desired effects will be produced; in short, he must have *faith*. There are countless instances outside the realms of mental healing to prove this, notably the cases where people have taken astringent pills by mistake, and have yet been purged because they expected to be. In one particularly amusing incident, a doctor gave a man a prescription for an affection of the stomach, saying, "Here, take this!" Later, when the patient returned to render thanks for his recovery, the physician had forgotten the remedy he had used, and asked to see the prescription. He was naturally somewhat surprised to hear that the man had swallowed the paper, and had taken no other medicine. In this category, also, belong the cures from amulets, charms and incantations. Every doctor of experience will admit that confidence on the part of the patient, and expectation of recovery are half the cure.

If now, these ideas are well founded, and mental states will cure functional disorders as well as those of the circulation and nervous system, why not abandon medical treatment altogether, and adopt some form of mental therapeutics—accept the beliefs of the christian scientists? Well, in the first place, mental healing will not work on all people; some can not accept the requisite theories; others do not seem able to produce the essential mental states; and others are so violently opposed to the whole system that exactly contrary results appear. Next, the methods are unreliable; they will work at one time, and later fail on the same person under apparently identical conditions, while the healers generally are not skilled enough to bring about satisfactory effects, for the whole system is in the hands of unscientific persons, whose methods outrage common sense and arouse hostility toward the many excellent features of their philosophy.

Most important of all, mental healing is powerless in very many kinds of illness, including most of those which are fatal or even dangerous. If mental healing is resorted to, the disease may become established before its nature is recognized, and the patient may die, when if he had been treated by regular practitioners he would have recovered. In all contagious and infectious maladies the patient becomes a menace to the community, since quarantine and disinfection are prohibited by the mental healers, as tending to confirm the patient in the "claim" that he is ill.

While the exact method of the action of drugs is uncertain, and many are probably inert, if not harmful, we are positive that certain ones, like quinine, mercury, opium, digitalis and others produce certain definite conditions which can be relied upon to assist the patient. Some of them kill the germs, just as boiling destroys the microbes of typhoid fever in water; others, like quinine, render the human body an unfavorable culture medium and discourage the "bugs"; others directly stimulate the action of the organs.

Even the more advanced mental healers admit that, at present at least, they are unable to treat with success surgical cases, which should at once be examined by a regular surgeon. The former err, however, in refusing to use antiseptics when prescribed, as they are rarely able to practise aseptic methods.

In addition to drugs, modern medicine is making great use of serums of various kinds, and antitoxin has rendered diphtheria, once a household terror, a relatively non-fatal malady. Further advances are being made daily along these lines, and great discoveries may be expected from the investigations of Metchnikoff into immunity and ferments.

Mental healing also errs in not employing to the full diet, fresh air, exercise and the other hygienic systems, which are rapidly growing to be our chief reliance in the control of illness.

It is a source of wonder to those who are following the subject that the usually acute leaders of mental healing do not profit by the experience of the Fathers at Lourdes. The latter have every patient examined by physicians, trained in the regular schools, before mental healing is attempted. This gives an opportunity to eliminate the dangerous or contagious maladies, while at the same time furnishing proof of cure and establishing the nature of the disease. It would seem possible to arrange this so as not to undermine the faith of the sufferer, as the process at Lourdes seems to meet with the approval of the Fathers.

The great weakness of the schools of mental therapeutics seems to be faulty diagnosis. In fact, there is apparently no attempt at diagnosis, and all patients are treated in the same general way. Thus time and strength are wasted on cases which are, from their very nature, hopeless from the start, and in which mental methods are absolutely criminal, on account of the danger and suffering of the patient and the probability of propagating disease in the community. It is not too much to say that no case should be treated mentally until it has been examined by a graduate of a reputable medical school, and pronounced not dangerous to the neighbors or likely to result fatally to the patient. It is for this reason that there is justification for the movement to restrict the practise of mental medicine, which would otherwise be an unwarrantable interference with individual liberty. It would seem possible to compromise the various warring interests, by requiring all mental healers to pass an examination, before receiving a license, in anatomy, physiology and diagnosis.

The whole subject is one which calls for tolerance and impartiality. Both sides claim too much. We have reason to believe that a very large proportion of all maladies can be materially assisted by mental healing, either alone or in connection with medical treatment. Even surgical and infectious cases may be benefited by improving the general tone and keeping up the spirits of the patient. In many ailments, however, this system is absolutely useless, while in another class regular treatment is unavailing, and mental methods are likely to succeed. It is a hopeful sign that a few physicians are devoting themselves to mental therapeutics, and that others send their nervous patients to the christian scientists. There is a field for both, and the two schools ought to work in harmony. One great bar to this is the prejudice, not only of the medical profession, but of the more intelligent portion of the community, against the new system, well founded, without doubt, on manifold errors, abuses and unreasonable claims. On the other hand, while there is much in the philosophy of christian science which is satisfactory to many minds, especially the portions resembling the Hindu beliefs as developed by Kant, the rest is illogical and irrational, and can not be accepted by thinking intellects.

The christian scientists have undoubtedly made many useful advances, mostly by pure empiricism, but these results are not essentially bound up with the christian science beliefs, and can be applied fully as well by any of the other christian churches. These methods can be studied, and are at the service of any one who will take the trouble to master them. It is a fact that they will work just as well with a pagan religion as with a christian one, as a doctor can cure a Chinaman of malaria as readily as an American. On the other hand, while the processes of mental healing can be applied by any one, and are being used daily unconsciously by many medical men, yet the essential elements are more easily furnished by the church, and it is most encouraging that one of the episcopal churches in Boston is adopting mental healing with gratifying success. The emotional nature of man, which controls mental healing, is intimately connected with his higher aspirations, and belongs rather to the domain of religion than to that of medicine.

A VISIT TO THE HANGCHOW BORE

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II

The Great Sea-wall

JUST when and how and at what cost the present substantial sea-wall was built are now matters for more or less conjecture, the chroniclers of the province neglecting such information as irrelevant in comparison with fanciful legends to be retold in connection with so great a work.[3] One of the most interesting of these stories refers to what was perhaps the first attempt at anything like an adequate sea-wall. It is to the effect that in the region of Emperor Huang Wu (25 A.D.) an official, Hua Hsin, proposing to build a sea-wall opposite the present site of Hangchow, issued a proclamation offering 1,000 "cash" (about fifty cents gold) for every man-load of earth that the people should bring to the river bank. On the appointed day great crowds of men, women and children came to carry earth. At a signal every one took up his load and carried it to the spot indicated by Hua Hsin's lieutenants. At this juncture Hua Hsin himself appeared and, feigning surprise when told of the large wage to be paid per man-load, he ordered the people away, saying it was utter nonsense to talk of such high pay. Indignantly the people threw down their loads and walked away, thus unwittingly dropping the earth just where the wily official wanted it. "Thus in one day Hua Hsin, by his trickery, built a sea-wall of great height, and one that withstood the briny waters for many years."

In spite of this assertion of the native chronicler, however, a dyke built in this fashion was sure to prove too flimsy to withstand the impacts of such tides as sweep the bay, and we are not surprised to find frequent references to daily sacrifices and prayers to the Water Dragon for protection against the powerful waters. It was not until the period of the Five Rulers that these prayers were answered by the appearance of a man of works as well as of faith, the "great Prince Ch'ien," Hangchow's most famous man. Many places of interest about the city still bear his name in recognition of his great services to the people, which included besides the less tangible, though none the less real, benefits of a wise and capable government, the more "substantial" benefits arising from the efficient fortification of the

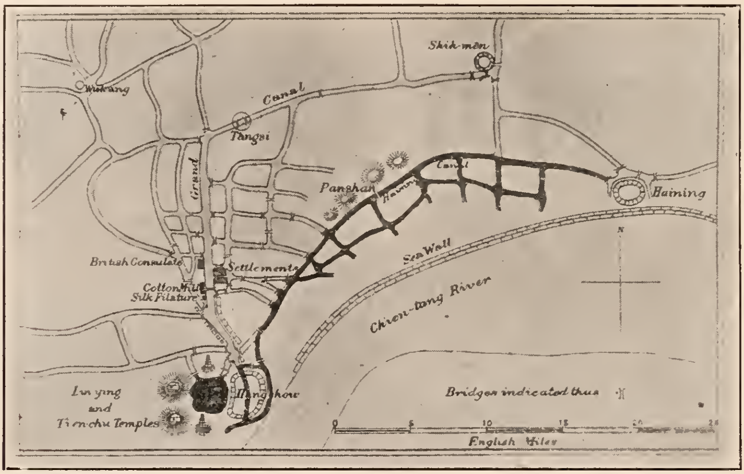
[3] For a fuller account of these legends see F. D. Cland's "Hangchow," Shanghai, 1906.

Along a Side Canal.

On a By-way Canal.
(Taken in the rain.)

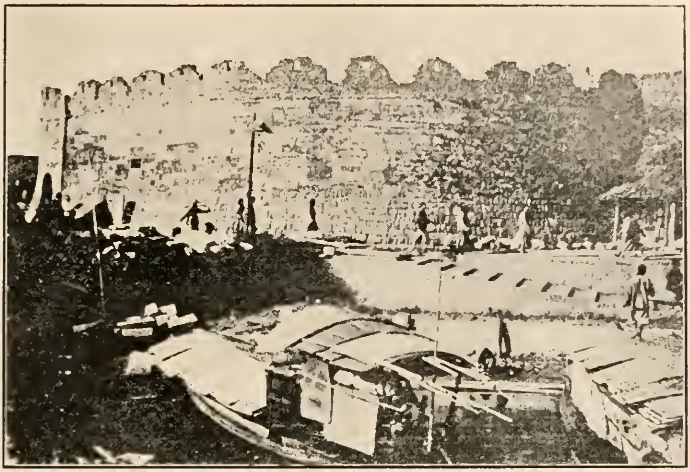
capital city, the preservation of the West Lake as a water-supply, the building of public roads, institutions of learning and canals, and, in view of the present considerations the most worthy of all, the long sea-wall which stands to-day as the greatest monument to his skill and efficiency in caring for the public weal. Its erection was begun probably about 911 or 915 A.D. It extends from Hangchow to Chuan-sha near the mouth of the Whang-pu (the river on which Shanghai is situated), a distance of one hundred and eighty miles. It is a stupendous piece of work and deserves an equal share of fame with the Grand Canal and the Great Wall of China, for its engineering difficulties were certainly infinitely greater.

Unfortunately there appears to be no record of how these difficulties were really overcome, although as usual the native historian



WATER-WAYS NEAR HANGCHOW. THE HIGH-LEVEL CANALS SHOWN DARK.
(From Decennial Reports C. I. M. C., 1892–1901, Shanghai, 1906.)

has felt impelled to leave a rather poetic narrative concerning an achievement so vital to the inhabitants of so large a region. Considerably abbreviated, it is to the effect that by petitioning Heaven to withhold the tides for two months and inditing a poem to the Water Dragon, beseeching the loan of the water's control for a brief time, the energetic and dauntless Prince Ch'ien was enabled to prevent the thousand sprites and the one hundred demons from bringing in the tides by having five hundred skilled archers shoot three thousand specially prepared arrows directly into the oncoming billows. Each man took up six arrows, one for each billow, and when they had shot five arrows straight into as many lofty waves, the waters suddenly turned and fled! Whereupon the Prince quickly drove great piles along the river bank, among which strong creels of bamboo were woven,



City Wall and Gateway at Hainung.

the whole being filled with earth and large stones. "Thus he connected the two ends of his wall and shut out the destructive waters," and thus, we may add, does the chronicler avoid telling us the essential details of the very part of the construction, which in its successful accomplishment constitutes the chief wonder.

But it was not enough simply to build the wall; it must be kept in repair, and, curiously enough, the native chroniclers have accounted most minutely for the cost of the up-keep, which is said to be on the

Hainung Pagoda and Pavilion.

THE BORE WALL AT HAINING, SHOWING THE SEA FOOT.

average 250,000 taels per annum, which has led many people of this region to call this sea-wall "China's Second Great Sorrow," giving place to only the Yellow River as her "First Great Sorrow."

For purposes of management and repair the wall is divided into three major divisions with a superintendent over each. These divisions are again divided into many sections about a mile long, and for each mile there are at ordinary times four to six watchmen who patrol their section much as railroads are patrolled.

The first cost of construction must have been enormous, and the mere existence of the wall suffices to show that it must have been of vital importance and that the land it reclaimed and now protects must have been of immense value to justify such an expenditure.

As it exists to-day its total length is one hundred and eighty miles, and for one third of this distance it is faced, as at Haining, with heavy blocks of granite and varies from twenty-five to thirty feet in height above low water. Each successively higher layer of granite slabs recedes about five inches, thus forming steps, a very welcome arrangement when, after descending to get camera views of various parts of the wall just before a bore was due, we had hastily to retreat before the oncoming flood.

The main difficulty in maintaining an efficient sea-wall would seem to be to have an outer footing adequate to break the first violence of the incoming bore and to prevent the undermining of the foundations of the main bunding—in fact it would seem essential that the tides should be entirely kept from entering behind the wall. At Haining the Chinese engineers have succeeded in accomplishing this very satisfactorily in a twofold fashion—viz., by a sea-foot proper and by frequent projecting "buffers," a combination which, besides giving a substantial sea-barrier, also affords excellent and frequent refuges for the junks whose masters must needs brave the dangers and difficulties of navigation in a river so fiercely tide-swept as this is.

At the level of the sixteenth ledge from the top, in this step-like face of the wall just referred to, *i. e.,* about twenty feet below the top of the wall, there extends outward a heavy granite platform several layers deep and about fifteen feet wide. At the outer edge of this several rows of piles are set close together and deeply driven into the river-bed. Here there is a drop of four or five feet followed by another shelving granite platform, somewhat wider than the first and similarly edged with several rows of much heavier and more numerous piles. Here there is a further drop of six or eight feet to a sandy beach which for a yard or two is rock strewn and studded with piles, a ragged fringe of which about ten feet farther out marks the outer edge of this remarkable barrier.

At intervals of half a mile, at least in the immediate vicinity of Haining, huge projecting buffers in semi-elliptical form have been built of brush and piles. The ends of the brush, which has been stacked and interwoven in horizontal layers, are presented on all sides and down through the mass several concentric rings of stout piles have been

FROM THE TOP OF THE SEA WALL DURING THE AFTER-RUSH. COMPARE WITH THE LAST PICTURE AND NOTE CHANGE IN WATER LEVEL.

View from the Top of the Sea Wall, showing the Successive Ledges of the Sea-footing and a Buffer in the Distance.

driven. These buffers are slightly higher than the sea-wall itself and also extend out beyond the last row of piles which forms the edge of the wall's sea-foot. Topped with earth which affords a rooting-place for bushes and small trees, they constitute a notable feature of this very creditable piece of Chinese engineering. Some idea of the destructive force of the bore may be had by inspecting the first buffer east of the pagoda. It is about one third demolished, so that instead of a well-rounded form it now consists of four or five distinct terraces, which are probably constantly settling down and pushing the lower terraces into positions affording less resistance to the tide. On the other hand, the buffer just west of the pagoda is in splendid repair and behind it high up on the topmost granite platform several junks were enjoying a safe shelter.

The stones on the top of the wall are from twelve to sixteen inches wide, sixteen to eighteen inches thick, and from three and a half to four feet long, and most of the blocks used both in the wall and in the platforms of the footing seem equally large. Along the top of the wall adjacent stones are fastened together by heavy iron mortises in the shape of a double wedge (⧗) four or five inches broad, two linking each pair of stones. Whether the lower layers of blocks are mortised in the same way we were unable to determine, though a friend has reported that he has observed these links also in the slabs forming the footing-platform, but we saw none in the part we examined.

On the top of the bunding from Hangchow to beyond Haining, about forty-five miles, there is a broad earth roadway, suitable for riding or even driving, though the latter might be risky, a unique country road. Back of the roadway there is a further embankment some ten feet high and about fifteen or twenty feet thick, which completes the barrier to the encroachment of the boisterous tides. Practically all of the houses near the river are built on levels lower than this bank.

The Haining Pagoda, which has been mentioned already, is apparently not very old and was probably built by a Buddhistic believer in *fung shui* as a protection to the bund and the city against the ravages of the "serpent's head." It is a fair specimen of its class, and certainly forms the most prominent eminence on that section of the wall, and, together with the more recently constructed pavilion just below it, serves well to mark a vantage point from which to view the approach and passage of the wonderful wave which sweeps past at every tide.

A Buffer at Closer Range.

The Buffer, or Buttress, to the East of the Haining Pagoda, broken down by the Bore.

The Bore

We first witnessed the bore on the night of September 5, 1906, really in the early morn of September 6. Arriving at the pagoda at midnight, it was not long before we could distinguish a distant murmur which increased very gradually for an hour, and was the more im-

Further Detail of the Above Picture.

pressive because nothing could be distinctly seen, the night, though scheduled for a full-orbed moon, being dark and rainy.

After about half an hour ripples and slight wavelets began coming in just as for an ordinary tide in most places, but with greater rapidity and frequency. At 1 A.M. the murmur had become quite loud and amounted almost to a roar with a sort of thumping; presently the very splash of the on-rush could be heard and at 1:15 A.M. a wall of water passed with a speed of about eight or ten miles an hour, and eight feet high, coming almost straight in along the axis of the river, but curving concavely, and with the highest part in the center. After its transit, the roar was soon lost in the sound of the steady rush of water; then huge and rapid waves and swells came in obliquely with great force, striking the wall at about twenty or thirty degrees and generating a great whirl and splash. This lasted about fifteen minutes and then there was a rather sudden decrease in the size of the rollers, the rising water now being increased by more gentle but still very rapidly moving crests. The inflow was still continuing at 2:30 A.M. when, deserted by our native guides, we were forced to return to our little boat in the canal near by.

The forenoon of September 6 was spent in an examination of the sea-wall for a length of some three miles in the vicinity of the pagoda, the results of which we have already noted.

Evidently we were correct in expecting the bore for that day to be a big one, for a great number of Chinese had come out to witness this never-ceasing wonder, and a considerable group had to judge for themselves of the efficiency of our binoculars in extending the range of vision seaward.

Judging from the ease with which the preliminary murmur had been heard the night before, we were confident of being warned of the formation of the bore in plenty of time to watch its formation from the beginning. But curiously enough this premonitory murmur was not anything like as distinct in the daytime as at night, and while closely examining the structure of one of the brush buttresses, we were surprised by the cries of the natives as they descried to seaward the faint white line which marked the birth of the bore. This was at 12:30 P.M. Bringing our glasses to bear on this line which seemed to be near the meridian of Chishan, a conspicuous hill about twelve miles east by fifteen degrees south from Haining, marking the indentation previously referred to as Bore Shelter Bay, we could see that the bore had formed in two branches. The one on the north side of the channel was considerably the larger and was advancing almost directly up the river, touching the sea-wall with its northern end and the sands with its southern extreme; the other branch was approaching from the southeastward and touched the sands on both sides. The advance line of the first was not so very high, but still we could see it miles away running along the curve of the land, while behind it came a mighty wave, the whole advancing practically at right angles to the northern shore, while the second or southern branch came on almost parallel to the shore and with increasing speed.

This latter line gradually curved around and when about five miles from Haining its northern extreme overtook the southern extreme of the first, thus forming a continuous line of white breakers two or three miles long. Where this juncture was effected great waves, white from the force of impact, dashed many feet into the air in mid-stream and seethed all about the point of conflict. This immense upheaval, however, rather quickly subsided, and the flood wave resumed a more

Junk on Refuge, which it reached on the After-rush of a Previous Bore.

or less uniform height, which presently increased as the bore contracted in width, and increased in speed as it conformed to the narrowing channel of the river.

With rapidly increasing roar and steady progress this line advanced, and the immensity of the phenomenon began to be appreciated even more than on the previous night. A wall of very muddy water, white-crested and fully ten feet high, was approaching with the speed of a railroad train, breaking over and overwhelming the resisting ebb tide of the river, which in front of the pagoda was still running out with a speed of six or seven miles an hour and fighting every foot of the monster's advance. It was a battle of the flood against the ebb, and the flood, backed by the irresistible power of the ocean's rhythmic pulse, was swallowing up the ebb with an on-rush which must be seen to be fully appreciated.

At two miles from Haining the flood-stream, probably that from the southeastward which appeared to run through the other, charged into the sea-wall, the violent rebound from which caused a tumultuous upheaval of the waters several hundred yards behind in waves twice as high again as the front of the bore.

As the northern end of the bore struck one of the buttresses, its line of advance was deflected and it came on with a curving and recurving crescent front, the ends being thrown forward of the middle

A Junk Refuge—the Junk shown in Previous Pictures is lying on this Refuge to the Left of the Part here shown.

portion by several hundred yards. This deep graceful curve in the line of the turbulent waters was undoubtedly due, aside from the deflection caused by the buttresses, to the swifter current in the center of the ebb, unwilling to the last to admit defeat.

As the bore passed Haining at about 1:45 P.M. it had somewhat the form of a double crescent, over a mile long and eight to eleven feet high, traveling twelve or thirteen miles an hour; its front a sloping cascade of bubbling foam, falling forward and pounding on itself and on the river before it at an angle of between forty and seventy degrees, the highest and steepest part being about six hundred yards off shore over the deep channel of the river. Close by the northern bank or sea-wall the height and rush were not so great because of the projecting buffers

THE SAME VIEWED FROM THE OUTER EDGE OF THE SECOND LEDGE OF THE SEA-FOOTING.

just east of the pagoda, and yet now and again the bore swelled up to the wall as it sped along. The southern end, meeting an incline of sand which rises only nineteen feet in a mile and a half, trailed away in a line of very deliberate breakers, which ceased half a mile to the rear of the bore or where it had passed three minutes before.

A second smaller bore followed directly after the first in the form of a group of secondary rollers on top of the first body of water, and several hundred yards in the rear of the crest behind which for many tens of feet the rushing water was churned into foam by the turmoil. These secondary rollers leaped up from time to time as if struck by some unseen force and disappeared in heavy clouds of spray. These breakers on the top of the flood were sometimes twenty to thirty feet above the level of the river in front of the bore, while the conflict in progress on the river-bed itself was clearly evidenced by the quantities of mud, sand and even large gravel which were seen to be mingled with the surging waters.

The river filled up to the level of the bore soon after it had passed, but not evenly.

A quarter of an hour after the bore had passed Haining, the water had risen thirteen feet; after two hours it had risen eighteen feet; and a high-water mark of nineteen feet was attained at 4:45, or after three hours of flood tide. At this time the stream commenced to run out swiftly. At 6:45 P.M. mean level was reached and at 9:45 it was practically low water again, though the out-going stream continued to run rapidly eastward until the arrival of the midnight bore, the water being at its lowest for the two hours preceding that event.

One of the most surprising features of the whole phenomenon is the sudden change in the aspect of the river. Just now we saw the muddy bottom bare for some distance from the shore to where the mid-river current was swiftly out-flowing, and a few minutes later the whole basin is filled with muddy boiling water, which seems to threaten to wash away even the substantial sea-wall on which we stood.

After the passage of the bore and during the in-rush of the after-body a number of men, some of them probably the duly appointed patrols, others not, appeared on the sea-wall with very long bamboos, some furnished with hooks at the end or spikes, some with rake-heads and others with loops of rope, all designed to enable their manipulators to gather in the driftwood, consisting chiefly of the loosened or broken piles of the outer protecting ledges of the dyke. One fellow was seen marching off in triumph with two whole piles and a half.

During and just after the passage of the bore a busy scene was also enacted on board the junks resting so securely on the platform along-

THE SAME JUNK AS IN THE PREVIOUS PICTURE, SEEN FROM THE TOP OF THE WALL.

side the bund and behind the buttress of brush and piles. The bore passed them harmlessly by, merely drenching them with spray. The flood following behind, however, quickly floated them off this place of security, but with a few turns of the ropes, the junks were quickly remoored and continued to ride safely on the racing tide. This accomplished, their loading was hastily completed, and within an hour they were away for a fresh destination up stream, or, waiting two hours longer, were able to effect an outward passage.

It was a curious sight to see the other junks, which previous to the formation of the bore were sheltering in Bore Shelter Bay or behind the islands out beyond the mouth of the river, come riding swiftly

Aspect of River Two Minutes before the Arrival of the Bore.

in amid the after-rush, past Haining toward Hangchow, with all sails set but with their bows in every direction. On the days we observed there were each time a baker's dozen of them, but sometimes as many as thirty junks may be seen utilizing tidal energy for ascending the river at a speed exceeding that of an ordinary steam vessel of equal size. As soon as they could steer a little, they made for the shelters behind the buttresses, where they allowed themselves to be stranded by the falling tide.

Steam vessels, not being able to follow the junkmen's method of avoiding the difficulties of navigation, can not use the river. The imminent danger to which those attempting it would be exposed might be inferred from the description we have given, and is clearly shown by the report of Captain Moore, R.N.,[4] who in 1888, in command of H. B. M. ship *Rambler* and two auxiliary craft, undertook a thorough survey of the river and estuary, which he continued in 1892, and whose vessels narrowly escaped total wreck.

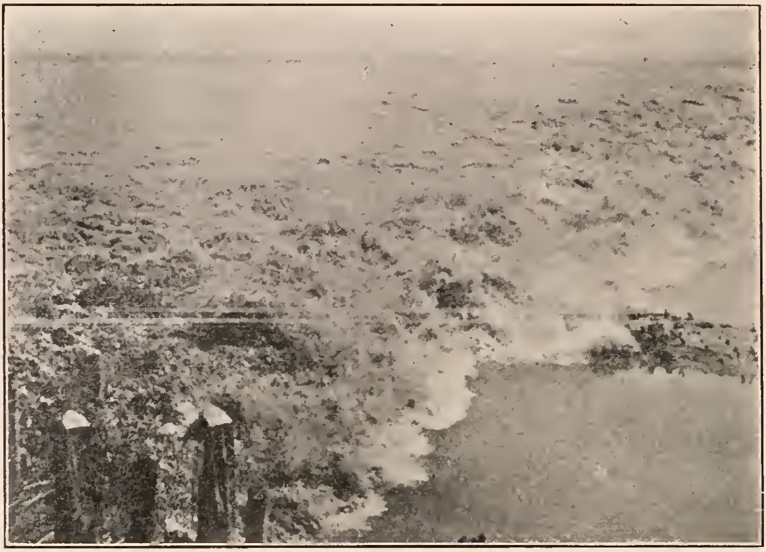
The Birth of the Bore as shown by Observed Water Levels

In this survey observations of water-level were taken simultaneously at three places: Volcano Island, away out at the mouth of Hangchow

Aspect of the River at the Same Place as the Last Picture, and Only Two Minutes Later. Wave Ten Feet High in the Center.

Bay; Rambler Island, fifty-one miles farther in; and Haining, twenty-six miles up the river. These measurements exhibit the nature of the bore very clearly. At 8:30 P.M. the water was one foot below mean level at Volcano Island, twelve feet below at Rambler Island and eight feet below at Haining. Thus the water sloped down from Haining outward to Rambler, and also downward from Volcano inward to Rambler; the water was running up the estuary toward Rambler Island, and down the river to the same point. By 9:30 there was no great change, but the water had risen two or three feet at Volcano Island and at Rambler Island. By 10 o'clock the level was rising rapidly at Rambler, so that there was a nearly uniform downward slope

[4] "Report on the Bore of the Tsien-Tang-Kiang," London, 1888. "Further Report," etc., 1893. Also, in *Proceedings of the China Branch of the Royal Asiatic Society*, 1888.



Bore Front, Thirty Feet High, a Few Miles below Haining.
(Negative of John Green, Esq.)

from Volcano Island inward to Haining. The rise at Rambler then continued to be very rapid, while the water at Haining remained nearly stationary. This state developed until midnight, by which time the level had risen twenty-one feet at Rambler and about six feet at Volcano, but had not yet risen at all at Haining. Through all this interval the water was running down the river from Haining toward its mouth.

This state of strain represented by a difference in level of over twenty feet between Rambler outside and Haining only twenty-six

The Bore passing Haining.
Negative of C. Pape, Esq., Hanchow.)

miles farther in could not last long, and shortly after mdnight the strain broke down and the bore started somewhere between Rambler Island and Kanpu, and rushed up the river in a wall of water twelve feet high. Following the bore came the after-rush which carried the level up eight feet more. It is on this that the junks are swept up-stream as already noted. At 1:30 the after-rush ceased, but the water was still somewhat higher at Rambler than at Haining, and a gentle current continued up-stream. The water then began to fall at Rambler, while it continued to raise at Haining up to three o'clock, when the ebb set in. On the south bank, at any rate, for four or five miles inside the mouth of the river, the stream commences to run out strongly an hour before high water at Haining. The fall of the water in the ebbing tide is not particularly interesting, for there is no bore down-stream, although at one time there is an exceedingly swift current.

According to the reports of others, the height, speed and characteristic appearance of the bore's front are maintained for fifteen miles above Haining, after which the height decreases; and the wave passes Hangchow city about an hour and a quarter after passing Haining, soon after which it breaks up and gradually disappears, though an effect is reported to be felt at times at Yenchow, some forty miles farther up the river. At Hangchow the rise and fall does not exceed six or seven feet. At Haining, as we have seen, the flood usually lasts three hours; the ebb, nine. At Hangchow the flood continues for only one and a quarter hours and is nearly all in the bore proper.

When the moon is at the point in its orbit nearest the earth at the same time that it is full or new, or when there are strong northerly or easterly winds in the Chusan Archipelago, the bore generally arrives early off Haining, travels at a greater speed than usual, and is also higher. Natives have reported tidal waves at Haining with a height of over thirty feet. As we have already noted, the highest bore is generally expected on the eighteenth of the eighth moon of the Chinese calendar.

Chinese Fancies concerning the Bore

An account of Chinese fancies concerning the tides in general furnished by Professor Giles, may be found in Professor Darwin's book already referred to, and Captain Moore in his report notes a curious legend which ascribes the origin of the bore to the revengeful workings of the spirit of a certain popular general who was assassinated by the Emperor through jealousy of his growing power, and whose body was thrown into the Ch'ien-tang Kiang. Later the Emperor sought to check the devastation of the country which arose from this source by making appeasing sacrifices on the sea-wall; but without effect, and it was at last decided to induce good *fung-shui*[5] by erecting a pagoda where the worst breach in the embankment had been made. This is the pagoda already frequently referred to and which is still in good condition. "After it was built, the tide, though it still continued to come in the shape of a bore, did not flood the country as before."

Fanciful as these ideas are, it is not at all surprising in view of the awe-inspiring phenomenon which recurs at every tide, and with which the inhabitants have had to cope perhaps from time immemorial, that they should think of it with reverential superstition as the head of a monster serpent which must needs be appeased. As many as five or six thousand people have sometimes assembled on the sea-wall to propitiate the god of the waters by throwing in offerings at a time when the serpent under his control was raging at its highest.

Intermittency of the Bore

This legend taken in connection with the fact that Marco Polo, who in the thirteenth century spent a year and a half in Hangchow, does not include in his account, which otherwise pretends to great minuteness, any reference to the bore seems to Professor Darwin to indicate that the bore is intermittent, because the Emperor referred to is of undoubted historical existence and antedated Marco by some centuries. But Marco Polo's accounts are not to be taken entirely at their face value as to accuracy and faithfulness, and even if the bore did not exist in his time, the great sea-wall which was in all probability built when the Chinese historians claim it was built by Prince Ch'ien, viz., 911–915 A.D., must have existed, and it is hard to conceive how he should have failed to mention such a stupendous public work, especially when he seems to have been so keenly interested in the Grand Canal. Either, as some authorities suggest,[6] Marco Polo never really visited Hangchow, but got his glowing account of the city's wonders from some native poet without admixing the proverbial grain of salt; or else he was so enamoured with the gayeties of life at the capital that he could not spare the time to visit Haining or the lower estuary in person, but judged from afar that there must have been much shipping there, for to this he alludes in several places.

As Professor Darwin finally concludes, it is very uncertain whether the Hangchow Bore has been intermittent, but it is sure that it is liable to considerable variation, for reports by the foreign officers who headed the troops sent against the Taiping rebels show that the intensity of the bore was then (1852–1864) far less than it is to-day. The ex-

[5] *Fung-shui*, literally "wind-water," a much-used term in Chinese geomancy, signifying propitious influence of the controling spirits involved in any undertaking—perhaps the nearest simple English equivalent is "luck."

[6] Decennial Reports, Chinese I. M. Customs, 1892–1901, Vol. II., p. 4.

istence of the bore as well as its fluctuations probably depends on a nice balance between various factors, and the irregularity in the depth and form of the estuary renders impossible the exact calculation of the form of the rising tide. The heading back of the sea water by the natural current of the river, and the progressive change in shape of a wave advancing into shallow water, may combine to produce a rapid rise of the tides in rivers. "But the explanation of the bore as resulting from these causes is incomplete because it leaves their relative importance indeterminate, and serves rather to explain a rapid rise than an absolutely sudden one." "It seems impossible from the mere inspection of an estuary, to say whether there would be a bore there; we could only say that the situation looked promising or the reverse." ". . . as in many other physical problems, we must rest satisfied with a general comprehension of the causes which produce the observed result." The description we have attempted may serve to give those who have not seen such a wonder some idea of the really marvelous phenomenon, but the best way to become familiar with its characteristics is to go and see it for yourself.

RAILWAY ACCIDENTS AND THE COLOR SENSE

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IN considering whether some of our frequent railway accidents may not be due to the character of the signals we employ, it should be borne in mind that these signals often must be caught and instantly translated into action under conditions of uncommon mental stress. And for this reason, defects of the symbols which might otherwise be far from serious do now become of vital moment. Yet it has been said that the work of the locomotive engineer seems to the observer more difficult than it is—that the long training through which these men must pass permits them to carry lightly their great responsibilities. It was the more interesting, therefore, when, on an express-engine not long ago, we had come to the end of our long course, and the din and jostle had given way to calm, to hear the engineer speak of the tension of his work. He had been at the throttle but three hours that day, and after going for a time to the round-house, would take his express back over the same run that night. "My partner," said he, "will have the run to-morrow. No man could stand it, holding her down in this way day after day." And so the engine crews on such a swift express lie off alternate days, and the engineer and fireman may not take out their train unless the entire preceding day has been a day of rest. Such carefulness on the part of a great corporation calls for praise which should be all the less restrained when so much must be said to-day of the shortcomings of our railways. Yet there could hardly be stronger proof of the strain under which the engineer must labor; for no company would give to its hardy servants every alternate day for freedom, unless experience had taught that the service itself required it.

Nor is it difficult to appreciate in some measure the severity of the work. Various duties that on an ocean steamer are distributed among helmsman, lookout, engineer, and the officer on the bridge, here fall chiefly upon a single man, and this where the care and instant judgment required seem at times to be not far below those needed for the guidance of a ship. The locomotive engineer must control a marvelously complex and ponderous piece of mechanism, keeping his sight and hearing and sense of shock so alive that amid the universe of whirl and glare and explosive rattle in which, for the time, he is centered, he can detect the foreign note or quiver that speaks of disarrangement.

He must know that his outside lights are burning bright, that the water in the boiler is sufficient, that the air-brakes are in perfect working. He must from moment to moment glance at the hands of his watch, and must know exactly where he is upon the road. And yet all the while his eyes must hardly be taken from the darkness into which his engine rushes, to catch the first glimmer of the signal which is his guide.

Since the safety of many lives thus depends upon these signal lights and upon their sudden clearness to a mind that must attend to many things at once, the symbols should at all times be the least ambiguous that can be planned. Yet the present night-signals, given by colored lights beside the track—upon many roads, white for "safety," red for "danger," and green for "proceed with caution"—are open to grave objections. For the human eye at its best and without abnormality is liable to mistake the signal hues at night, especially when the outward conditions are anywise untoward, whether by the distance or the low-burning of the lamp, or by fog or smoke or storm. And even when the colors are perceived with perfect accuracy, the use of the common oil-light called "white," as one of the signal colors, throws a dangerous task upon the engineer, inasmuch as it requires him to take constant heed lest he regard some window-lamp, or other meaningless light along his course, as a sign that all is well, and in consequence rush onward to his train's destruction.

That objections of this character are supported by strong evidence, and are not of merely theoretical importance, but are connected with actual and known disasters—to make this clearer is one of the main purposes of the present paper.

In regard to the use of white as part of the signal code at night, the danger from this source has long been recognized by leading signal engineers, although in spite of this recognition its use continues on a large number of our American roads. It is not many years ago that an accident occurred at Whittenton Junction, Massachusetts, from this very cause. The engineer mistook a lantern hanging from the gate at a street-crossing for his safety signal, and crashed into another train. More recently, Mr. Baggett, of the Galveston, Harrisburg and San Antonio road, has given an instance where disaster resulted from the use of white. The railway signal, in this case, was exactly in line with a light shining from a high bay-window; and when the signal light itself one night was out, the engineer mistook the light in the window for his signal, and a serious accident was the outcome. And other cases are reported by the Interstate Commerce Commission. A switch light happened one night to be extinguished, and the engineman "failed to notice the absence of the light, being deceived, he says, by lights in the vicinity"—a deception which brought damage amounting to $3,500, a maiming and a death. On another occasion an engineman runs past a signal which the station agent declares was set at "stop," but which the engineer himself asserts was showing "clear." Immediately after the passage of the train, the signal light was found to have been extinguished, as it had been once before that evening; it is not improbable, therefore, that the "clear" light which the engineer saw was some neighboring light which he took to be his signal. His mistake brought death to 18 persons, injury to 57 more and a loss of $15,720.

With this evidence of the danger which lies in using white for color signaling, and before passing on to consider red, a word should be said of green—a color which, partly by its strong contrast with red, its companion in the system, has found most wide acceptance. Green stands out distinct from the common lights of street and house; it readily makes an impression upon the normal eye. But persons who are not color blind are liable to be weak in their sense of this very color. And smoke, one of the great disturbers of signals on the railway, has a serious influence upon green. For smoke, which makes white or yellow lights look red, does this by making ineffectual the very rays that are so important for giving a green light its greenish cast. The simple experiment of holding a smoked glass before a green railway-light will easily show how hostile smoke is to the passage of green rays. Now when, for this or any other reason, green comes dimly to the eye, especially when sight has grown accustomed to the dark, it has the misfortune of appearing, not green at all, but a pale and ambiguous light that is indistinguishable from white. Under such circumstances, especially upon those roads where both white and green are signal colors, the danger of their confusion is not imaginary; nor is the danger of green's total obscuration slight. In the records of the Interstate Commerce Commission occur more than one instance where the failure to observe at night a "distant" or "caution" signal, which is often green, has been an important part of the cause of fatal accidents.

But after all, the core of the present system is red, and to this our main attention should be given. The color is usually obtained by bringing before the semaphore lamp a glass which, acting like a filter, permits the passage of those rays that are red or reddish, and holds back from the eye all other light. Such a ruby glass, by killing off in this way all that portion of the flame's light which is green or blue or violet, and often all that is yellow, does of necessity greatly reduce the brightness of the signal, leaving it in many cases about one fifth as intense as when, by the signal mechanism, the red glass is removed from the front of the lamp. This readily explains—what any one can observe—that in a cluster of signal lights equally remote, the white signals normally outshine to a marked degree the neighboring signals that are red. This, of itself, is an undesirable condition, since the sign of danger should of all be most outspoken.

The disadvantage under which the red danger signal labors is, however, quite insufficiently expressed by saying that the ruby glass often virtually destroys fully four fifths of the light from a lantern flame already none too bright, and to this extent increases the liability that the most momentous of the signals will at some crisis be seen too late or not at all. Even the remaining portion is often far less effectual upon the eye than its physical quantity would lead us to expect. The importance of the matter for signaling will perhaps justify some further account.

If, by reliable devices of the laboratory, a semaphore light showing "white" be gradually reduced in brightness, a point can easily be found where the eye, grown accustomed to the dark, can just perceive the light. And when for comparison a railway ruby glass, or "roundel," is placed before the lamp, the observer now obtains no conscious impression at all. But instead of having to increase fivefold the brightness coming through the glass (as one might expect, knowing that the red glass is pervious, say, to but one fifth of the light of the flame), it is necessary to increase it no less than fourteenfold. Such an increase is the least I have found necessary when experimenting at night over a stretch of more than four thousand feet and when smoke gave a relative advantage to the red. Within the laboratory the red has never been perceptible until the light was increased eighteen times the brightness required for white. Such, however, are the most favorable experiments, and are by no means average ones. On the average it is necessary to increase the light as much as thirty times before any conscious impression at all is made by the light through the red glass. One of the subjects of this experiment—a man who would pass the usual tests for color-blindness—has still remained insensible to the red when the light is increased to seventy times what is needed for the white! Such facts as these show clearly that by merely looking at a cluster of railway signals, or even by taking the usual tests of their relative intensity or visibility when shining bright, we get no adequate idea whatever of the difficulty which the eye has with very *feeble* reds. And feeble reds are no great rarity in the actual conduct of trains. The many influences which render signal lights obscure thus act with a peculiarly fatal force upon the very color which is our chief reliance for the protection of life.

And the doubt thus raised regarding red is not allayed by the reports of railway accidents. For in these reports the frequency with which engineers fail to observe red signals at night is a most impressive fact. It is often impossible to tell assuredly why men at such times are unconscious of the danger sign; but even when allowance is made for the sheer carelessness of trainmen, or for exhaustion resulting in their sleeping while still on duty, there seem to be cases enough to warrant some suspicion of the virtue of the danger signal itself. In the summer of 1904 an engineer at night ran past signals at "stop," and into an open drawbridge with his train. About a year later, a disaster was caused by the failure of an engineer at night to heed two block signals and a flagman, the engineer himself losing his life by his mistake. On still another occasion, a train ran past three or four warning red lights, and by a collision with a passenger train ahead brought death to 23 persons, injury to 85 and a property loss of $7,000. And the inherent difficulty of perceiving weak red may have been a contributing circumstance to that wandering of the attention of an engineer who recently, after passing a "distant" signal obscured by smoke, failed to notice "until he was quite near it" his "home" signal telling him to stop, and crashed into the rear of a passenger-train. This failure to see in time the warning light cost seven lives, brought injury to no less than 142 persons and destroyed property amounting to $44,000. And finally, on the night of December 30, 1906, a collision occurred in the District of Columbia, due in part to the failure of an engineer to see a red light obscured by fog; and in this disaster 43 persons were killed, 63 were injured and property valued at $16,000 was destroyed.

These fearful results, depending, as they do, upon the failure to see red lights, diminish greatly one's confidence in this color. And this confidence grows still less as we bear in mind the many instances, which have not been adduced at all, of utter failure to observe the red "tail lights" of trains, red switch lights, or red hand lanterns—failures that ended in deadly accident. The insufficiency of a red hand-lantern carried down the track for the protection of a standing train is doubtless in part to be ascribed to the unexpected place in which these signals must of necessity be shown, and the engineers' unreadiness to note them; but it is not improbable that the very color of the signal contributes to its failure. We are accustomed to think of red as exceptionally impressive; and it truly is in many respects an effective light, attracting the attention when once the eye catches it in strength. But at degrees of illumination that would be ample for some of the other colors, it cease to penetrate the mind—somewhat as in photography, red of all colors has least effect upon the sensitive plate. Red may some day come to be regarded as a danger signal, with an unusual meaning to the words. And yet, taking all things into consideration, it is perhaps the best color to use as a sign of danger, if color must be used. Such a conclusion, however, reveals but too clearly the weakness of a system based on color—reveals how fatally mistaken it is to make the life and safety of passengers dependent upon the hurried recognition of colors at night by any man, above all by a man who has many and most insistent duties besides.

That the color-sense is wholly unfit for the office it holds in railroading is hardly open to any doubt whatever. One must speak with less assurance, however, as to what should take its place. But even here the general principle that might guide the change is reasonably clear. Our eyesight detects two different features in objects—their color and their spatial character, such as shape, position and movement; and the sense of color is far less primitive and vital and masculine than is the rude sense of space. Nature seems to have held the sensitivity to color a cheap and slighted accomplishment, to be crowded out or postponed to the mere finishing school, like young ladies' French and dancing. But the rugged feeling for place and direction is early given and pressed deep until it becomes a central fact in self-preservation and advance.

Now if the eyesight of the engineer is to be depended upon at all, it is this more fundamental and stable portion of it that should be given responsible work. If the practical difficulties could easily be met, the power to distinguish between rest and rapid movement of some conspicuous object would be the best to call upon in signaling. For we, like the bird and beast in the woods, are alive to slight quick movements in the field of view, far more than to color or even to shape and size. When the arms are waved or a lantern swung by hand to attract attention, appeal is instinctively made to this deep and primal interest in moving things. But next to this, the simplest and least erring of our visual perceptions is of large differences like that between a vertical and a horizontal line or one aslant. Now these rough and simple elements are precisely those used for the day signals of most block systems, where there is an extended arm placed high beside the track, and its direction of pointing—up or down or at some angle intermediate to these—tells the engineer whether the track ahead is open to him or closed or to be entered only with caution. Such signals make no prime appeal whatever to the sense of hue, but only to the sober feeling for visual place. And there seems to be nothing to prevent that this same principle of signaling should be carried over into the night and be even more successful there. For the extended vane used for the day signal often is before some unpropitious background of buildings or of trees against which it stands out in no strong relief. But at night it would be possible to use some self-luminous line of light that would appear sharp and unmistakable against the dark.

The detailed mode of applying such a general principle belongs to mechanical art rather than to psychology. But lest the principle itself should be misjudged for want of some more definite form in the mind, it might be well to imagine a row of incandescent lights inserted in the signal-arm now used by day, but lengthened and otherwise modified in whatever way its new work might require. Considerable intervals may be between the lights, and yet from a distance they will seem a continuous line; and as for length, experiment both in the laboratory and over a distant stretch at night shows that the main directions of such a line can be caught by the normal eye when the length is about a thousandth of the distance from which it is to be read. Three or four lights in a row about five feet in length would thus suffice for giving an engineer his signal a mile before he passed the post. A space signal given in some such way would naturally require more feeding of electricity or gas or oil—than does the single small wick flame that now gives forth the colored beam. But on the whole it would perhaps be well to spend fuel and light rather than life.

The mere imaging of a generous and glowing line to give the signal, will at once quiet some grumbling doubts that come from failures hitherto. Certain older attempts to use the space principle for railway signals at night could easily bring misgiving if the real cause of the failure had lain in the space sense itself. But, in fact, there has been no readiness to use the amount and extent of light needed for a proper signal. One of our roads tried to guide its trains by means of two lights whose changing position with reference to each other should give the sign to the engineer; and this signal was found unsatisfactory because these two lights blended into one when looked at far away. But for the most part the attempts have been confined to spreading out into a band, by means of a reflector, the light of a single lamp—a band of light that was too faint to be well seen when the reflector became dimmed by smoke or the corrosion of the weather. Such crude attempts to make a spatial signal were of course foredoomed to failure, and give no reason to distrust the perception of space itself. They simply prove that sufficient brilliancy of light must be maintained, and that this brilliancy must be stretched to sufficient length—conditions which can certainly be fulfilled at least wherever there are electric lights.

One can speak with greater confidence because of the practical success of such spatial signals in another field. The use of the luminous line is already well established in the navy. Two movable arms, each provided with a row of incandescent lights, here rapidly convey, by the direction in which they point, their message from ship to ship, or to the shore. And even with comparatively short lines of light, their position is legible by the unaided eye at a considerable distance. The outcome here gives ample reason to believe that it would be possible to apply the same general method to the railway service.

The advantages of relying on our space-perception instead of on the color sense will probably in time be recognized as far outweighing whatever difficulties there may be in the change. The new plan would merely require us to suppress the worse half of the present composite set of block signals—the half, which relies on color—and to render universal its better portion which already signals by direction. The present system would thus be simplified and fulfilled, rather that annulled, and there would be no need of training engine drivers to an unfamiliar code. And while the perception of the trend of a line of light requires that the refractive power of the eye shall be normal or shall be corrected by the use of glasses, the engineer's work even now demands that his spatial vision shall be keen, and thus no innovation would be made.

But even were there many objections to the use of spatial signals, they must be grave indeed to outbalance the fact that a line of light not only frees us from the treachery of the color sense, but gives a symbol that is distinct from the usual lights of the window or the street, and at a stroke renders well-night impossible those accidents that come from mistaking foreign lights for block signals. Moreover, we should then have a system wherein danger would be indicated at all times as clearly and as unmistakably as safety, whereas in the present code the red danger signal can too readily remain unseen. An important advantage besides would be that signals of the kind here proposed could hardly, by influence of smoke, or fog, or storm, be made to seem the very contrary of what they really were. A green light may look whitish, or a yellow light red, by mere conditions of the air. But a vertical line can not well be made to appear horizontal, or a horizontal diagonal, by smoke or fog. Its message might be cut off entirely, but could not readily be distorted into its fatal opposite. In this, as in so many other ways, a change of usage commends itself to the critical sense.

In urging that we no longer rely upon the color faculty for the safety of our trains, I have spoken almost exclusively of those difficulties which color offers to eyes that are entirely normal and sound. And upon such facts the main objection to the present system may well be based; for they are strong enough in themselves to condemn our usage and to demand that it be changed. But the reasons so far given are immeasurably strengthened by the existence of color-blindness and other defects of the sense of color. There are some men, it is true, who believe that the danger from this source is entirely averted by the current examination of engineers. No one would wish needlessly to lessen faith in such examinations. And yet it should be more widely known that defects of color vision are not always easy for physicians to detect; far less are they for laymen. And since many dangerous cases are known to slip through the meshes of medical examiners elsewhere, it is reasonably certain that the same is true with us. Dr. Stadfeldt, of Copenhagen, in a recent examination of 295 pilots (who, like engine-men, must distinguish colored signals), found 17 who were defective in their color sense. And Professor Nagel, of the University of Berlin, one of the great authorities in this department of research, and who has been called upon to assist the Royal Prussian Railways, has lately found in responsible positions like those of engine driver, fireman, switch tender, no fewer than twelve typical instances of red-green blindness among men whose sense of color had been officially tested and approved *four or five times.* Of about 300 employees of all branches of the service, all of whom had been tested at least once—and almost all of them more than once, by physicians and not by mere laymen—Nagel reports five per cent. to be typically color-blind; not color-weak merely, but actually color-blind. It is, therefore, difficult to partake of that happy confidence expressed by one of our leading railway journals, that "the railroads have long since done away with the dangers of color-blindness, by taking color-blind men off from their engines." We must, on the contrary, believe that the undiscovered presence of color-blind and color-weak men upon our engines adds to the many reasons for refusing longer to intrust the safety and life of thousands to one of the most fickle of our human faculties.

THE INFLUENCE OF TECHNICAL SCHOOLS

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THE increasing strength and efficiency of our applied science schools presages a period of industrial prosperity, marked not only by pecuniary profit to merchants and manufacturers, but also by the constantly improving condition of wage earners. But there are those to whom this prospect brings no comfort, for they see in it the foreshadowing of a period marked by decay of philanthropy and lack of piety, when a materialistic spirit will bring about a selfish individuality destructive of all that is good in society; they see its baneful influence already here, for young men avoid the college courses and rush into applied science to reach money-making as soon as possible; while not a few of them denounce the modernized curriculum in colleges as the disturbing cause and plead for restoration of classical studies to their former preeminent place as an all-important means of defense against the approaching calamity.

Those who have struggled to free the curriculum from medieval shackles would have no cause for mortification if they were responsible for the increasing attendance at schools of applied science; unhappily, they can lay no claim to the credit, since the matter in no wise concerns the contests between classicists and anti-classicists. Existing confusion respecting this matter is due largely to gradual development of the technical school within the college. Even now in the smaller colleges, applied science courses are parallel with those in pure science and in literature; students in all alike meet in many classes, assemble in the same chapel, mingle on the same campus; graduates in applied science receive the degree of bachelor in science as do college students taking pure science, and think of themselves and their fellow students think of them as having graduated from college. The confusion would have been less pronounced had there been a proper difference in degrees.

For, be it understood, the college and the applied science school are wholly different in character and purpose. The latter is a professional school, and its graduate has never been "at college," though he may have received a superior intellectual training and may have become in many ways a stronger, broader man than his friend of equal ability, who has B.S. or A.B. from some college with a narrow group or wide elective system. The applied science school is professional as are schools of law or medicine and differs from them only in that the essential prerequisites for admission are necessarily much higher.

The assertion, so often made, that young men are deserting the college courses is not well founded. Comparing the college catalogues of to-day with those of thirty-five or almost any other number of years ago, one finds that there has been no falling off in proportion of students taking college training—on the contrary, the number has increased far out of proportion to increase in population. In looking over catalogues of law and medical schools one sees that, among American-born students, the proportion of men with college degrees is much greater than it was thirty-five to fifty years ago.

But whence come the thousands of students taking the technical courses? In not a few instances, no doubt, they are sons of men disgusted with the wide elective or the narrow group systems prevailing in colleges; men, who, desiring to secure for their sons a broad training without reference to their future work, find themselves compelled to choose between narrowness and breadth, between college and applied science. They choose the latter even at the risk of failure to acquire some special forms of culture. In other instances, they are sons of intelligent men of moderate means, who have read addresses by university presidents and have noted the university methods. They have seen that in some institutions the fourth and even the third year were lopped off from the college course and that, in their stead, study for a professional degree was accepted as qualifying for the college degree. It is but natural that thoughtful men, unfamiliar with educational affairs, should accept the opinions of those popularly recognized as authorities in such affairs. They are the more inclined to this in view of the unjustifiably long period required by secondary schools for college and science preparation; and the conclusion is confirmed by the discovery that, in applied science schools of the higher grade, much is taught that is given in the two college years, which all agree are essential. Students belonging to these two classes are increasing in number, and they will continue to increase as long as the college curriculum remains in its chaotic condition; but they are still an insignificant minority. Comparatively few parents know enough to make intelligent choice for their sons, and most men, with means to give their children the luxury of a college education, prefer to have them follow the beaten track.

The overwhelming majority of students at applied science schools belong to a wholly new class. As has been said frequently, the sudden discovery of our country's resources, forty years ago, made necessary new types of training. The old-time country surveyor had laid foundation for lawsuits in important cases; the excellent pit-boss failed as superintendent of mines; the rule-of-thumb graduate from the cast-ing-house was a source of disaster in furnaces; while merely "practical men" were helpless before the great problems in railroad and other types of civil engineering. There was room no longer for uneducated surveyors, founders, superintendents, engineers. The skill demanded under the new conditions converted those "callings" into genuine learned professions, and schools of applied science were established to fit men for them. Most of the students in those schools, now receiving advanced education, can not afford the luxury of a college education course, and their increasing number is due simply to the great demand for trained men in subordinate as well as in responsible positions.

The assertion that men go into science for the money that is in it is merely a variation of the refrain with which the writer was familiar during his early student days, fifty years ago. Then, the attractions of business were the vile bait which lured men from the supposedly unselfish pursuits. But the plaint is unworthy of the men who make it. Students go into science as others go into law, medicine, or at times, even into the ministry, for the "money that is in it"—that is, to gain a livelihood in an honorable way. If a graduate in applied science have great energy, common sense and executive ability, the combination of business capacity with systematic training may put him eventually into a position of great responsibility with corresponding salary; but if he must follow his professional work alone, the prospects of acquiring a competency are about as good as those of the average clergyman.

It is unfortunate that our colleges have not made clear differentiation between students in culture and students in applied science. Failure to do this has brought about the tendency to confound pure and applied science, college and professional work, which is shown by many college graduates. If one recognizes this fact, he will be less surprised at the frequency with which technical schools are dragged into discussions respecting changes in the college curriculum. An excellent illustration of the tendency referred to appears in an address delivered at the inauguration of a college president a year or two ago. The speaker pled for classical training, as a classical college "is the best place in which to keep alive the heroic ideals of self-sacrifice and service." He said:

> It was urged when technical education began to be largely developed in our land and the classics were cast out from the training of young men and women—it was urged that this new kind of training in the precise and mathematical sciences would breed men of firmer principles. The technical schools of our land have not turned out men and women who see moral issues more precisely or who live more faithfully for the right things on earth than the young men and women who have had their education under classical influence. And the influence of our technical schools not alone has not bred firmer principle, but it surely has not bred finer sentiment.

And the proof of all this lies in the fact that the speaker had sought unsuccessfully in several technical schools for a man willing to teach mechanical and electrical engineering under missionary auspices in a foreign land. His argument was strengthened by the assertion of one president that the young men in his institution were not in engineering for the good they could do in the world, but for the amount of profitable employment they could secure for themselves. And the survey of conditions led to this forecast:

> I believe we are going to have to face in this land that inevitable result of our technical education. We have turned away young men and some young women from the great classical ideals of self-sacrifice in fields where they could do the most unselfish work.

These statements, made in all sincerity by one who is respected by all who know him, appeal directly to the prejudices of many who wish well to all mankind; but they are defective and the defect arises from confounding things wholly unlike and unrelated.

Technical schools are not schools for the study of science, but schools in which the principles of pure science are applied to practical operations. Like trade schools, schools of law or medicine, they are to prepare a man to earn a livelihood in honest and honorable fashion, to do well that which formerly was done in slipshod fashion. Mental and moral training, as such, have only incidental place, yet such training is as inseparable from their work as muscular training is inseparable from apprenticeship in blacksmithing. When one considers that students in such schools are taught to regard theirs as professional work of the highest grade; are taught to regard honorable dealing as the foundation stone of a successful career; are trained from the outset to recognize the great responsibility awaiting them, in that the security of vast properties and the safety of communities will depend upon their skill, accuracy and honesty; he can not doubt that even the coarse fiber of an unscrupulous man will undergo some refining during a four years' course. And the facts amply confirm the *a priori* conclusion. The writer knows that the moral standard among engineers of every type—chemical, civil, sanitary, electrical, mining, mechanical—is immeasurably higher than in the days when there were no technical schools, when the work of such professions was left mostly to mechanics. If the standard of professional honor were not high, very high, our national prosperity would come to an end, for all depends on the engineer.

There is no room for pessimism here. Men should thank God and take courage for the future as they see the influence of technical training, which has transformed the face of the world and led to increasing recognition of unity of interest. Improvements in mining and metallurgy have brought about improved methods of transportation and have cheapened products everywhere, while increasing the rewards of labor; the beef of our southwest and the wheat of the northwest can be sold in London at profit to the producer, and famine in any part of the civilized world is almost impossible; the coal of southwestern Virginia has been sold in Boston at profit for less than the freight to tidewater, thirty years ago, when the transporting companies were losing money; improved methods of refining petroleum have reduced the cost of illuminating oil to a small part of the price of thirty-five years ago, have carried light literally into the dark places of earth, have lengthened man's day by three hours and have given to agricultural communities a social and intellectual life previously impossible; mechanical and sanitary engineers have made possible the compulsory introduction into tenements of comforts and conveniences which, half a century ago, were considered luxuries even in the homes of the wealthy. These and a multitude of other changes for the better, due to men trained in applied science, for the most part in schools of applied science, have in very truth brought the ends of the world together and given us a better sense of the brotherhood of man. One may look forward confidently to the time when bricklaying will be as dependent on scientific principles as brickmaking now is, when the laborer will be a skilled workman and the mechanic a graduate of the schools; when in all our literary institutions training in every department will be supplemented by drill in the scientific mode of thought, that men may be taught how to make inductions safely.

That no young man was found anxious or even desirous of spending his life as teacher of engineering at meager salary amid undesirable surroundings, practically without any reward except that of a good conscience, is not surprising. There would have been ground for surprise if one had been found. No doubt similar success would have attended a hunt among law schools. It is probable that not more than a few score of persons had ever heard that teaching of engineering is a part of missionary work, and it is equally probable that no one, aside from the few score, had ever thought of it as a possibility any more than that of teaching American law. It might have been equally difficult, prior to the establishment of medical missions, to find volunteers in a medical school.

Men, desirous of spending their life in work merely for the good they may do or who are willing to devote themselves to their work for the work's sake, without reference to their own future or to that of their families, be they geologists, ethnologists or missionaries, are very few—and one may say, that, all in all, it is well for the race that the number of such self-sacrificing men and women is small. Persons of that type choose some course which will lead to the attainment of their object. Those desiring to be missionaries take either medical or theological courses, for along those lines missionary work is pushed, and the workers receive the reward which they regard more than they do money. When shopwork and engineering come to be held in high honor among missionaries, the technical schools connected with state universities will have their share of men preparing for usefulness. When that time arrives there will be no more insinuation that the technical school lessens respect for principle and weakens fineness of sentiment. At the same time, it may be remarked that labeling a man as selfish or without the finer sentiments, simply because he is unwilling to become a foreign missionary, seems to be a somewhat audacious assumption of the Divine prerogative.

But how does this question of the technical school concern the observance or neglect of classical studies in the college course? Not in any wise. Classical studies have not been thrust out of the technical school, for they never were in it; they have no proper place there any more than in schools of law or medicine. Whether or not prolonged classical training is desirable for those who can afford the college course prior to beginning preparation for life's work is certainly deserving of serious consideration; and there must be much to be said on both sides—otherwise, the discussion would not be intense as at present. It may be that classical training, as imparted in American colleges, is the best or even the only means of turning the youthful mind to high ideals—but the writer hesitates to accept the proposition. He underwent a very severe course of classical training from his sixth to his twenty-second year, yet his memory, by no means frail, does not recall "the great classical ideals of self-sacrifice" with which, one must suppose, modern ideals fade into insignificance. Nor has this conception of classical training been accepted always as axiomatic. The writer remembers an earnest discussion by several professors of theology at his father's table, about fifty-five years ago, in which those excellent men lamented the degrading influence of the classical authors read in college—the same, by the way, as those read now. And doubtless some of those reading this article will remember the efforts made by good men to counteract this evil influence by the preparation of works in classical Latin, dealing with the life of George Washington and other harmless topics. The writer, however, has never been able to share those fears. His general impression respecting the classical authors, which seemed to be that of his fellow students, was that those writers prepared their works chiefly to provide sentences with which Zumpt and Kühner might illustrate the perplexities of syntax and prosody.

KELVIN IN THE SIXTIES[1]

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THERE is the stereotyped teacher—the teacher who is like a collection of phonograph records which the human phonograph rolls out before his class in the same order annually—the talking text-book, who instructs his students what it will pay them to read, payment being made in examination marks—the type of teacher whose students, machine-made like himself, will grind out the tune, after the clockwork has been wound up, by due preparation on the candidates' part, the tune required written out by the examiner, and the clockwork started.

And, on the other hand, there is the great teacher, the inspired teacher, he who soars above scientific fashion, whose doxy becomes scientific orthodoxy, who produces thinkers, not mere successful examinees. Such was William Thomson, who became Lord Kelvin.

In the sixties, after the British Association Committee on Standards of Electrical Resistance had been started, but was still in its infancy, I had the rare good fortune to be one of Thomson's students. I, therefore, add to the many memoirs that have recently appeared a loving tribute from one who was at the Glasgow University when the quadrant-electrometer, the syphon recorder, the mouse mill influence machine, and many other instruments that have attained world-wide renown were being developed. Even after his severe illness in 1905 he never lost his keen interest in science, but at the time I am referring to he was not only a giant mentally, but of extraordinary physical activity.

When he came into his class-room, a room festooned with wires and spiral springs hanging from the ceiling like the rigging of a ship, he had hardly given a thought to what he was going to talk about—if it were Monday morning he had just returned from staying the week-end with Tait at Edinburgh, and he gave us an enthusiastic account of their talk, bubbled over with what they had been doing, was full of suggestions about it, told us how the manuscript of "Natural Philosophy" was progressing. We felt that we also had been discussing these points with Tait in his Edinburgh study, and listened with rapt attention to Thomson's narrative.

At that time the advanced proofs of only a fragment of that book had been printed off for the class. We saw the book grow, we felt pride in its growth, we almost felt that we were helping that growth.

[1] From the Engineering Supplement of the London *Times*.

That book by "T and T'," as is well known, consists of chapters which are more original than the papers usually read before scientific societies. Only one volume has ever appeared—the second, alas! alas! never will now.

To test the power of the Clarendon Press to publish such a book, Tait and he wrote down at random complicated equations, lines of wholly unintelligible reasoning, and then thought it would be a good joke to send out the proofs—as copies of an original paper—to various of their friends. And one day Thomson told me with a twinkle in his eye, "Nobody has yet found any mistakes in that paper."

Every morning, except Mondays and Saturdays, Thomson lectured twice; the first lecture, 9 to 10, was on experimental physics; the second, 11 to 12, on mathematical physics.

Electricity was the subject of the 9 to 10 lecture during a particular session which I have in my mind. But the experiments generally went wrong, and Thomson used modestly to say, "Faraday's result was so and so; mine is just the opposite. But Faraday, with inferior apparatus, *divined* the truth. Remember his result, not what you have just seen me obtain."

Thomson with all his genius, all his power of advising how an experiment should be made, with all his creative originality in suggesting the details of scientific apparatus and methods, could not make the experiments with his own hands. We all dreaded his touching the apparatus which we had set up and adjusted. He was too impulsive, too full of exuberant energy. After the apparatus was broken when he had touched it he was profoundly sorry. At that time it gave us the feeling that we were able to help him by trying experiments on his behalf. But this feeling resembled that of the calculator who helped Newton when he became too excited to finish the application of his principles to the explanation of Kepler's laws, or the feelings of the sculptor's assistant who transfers to marble his master's inspired creation in clay. We loved him the more that he allowed us to take a part—we felt that we were the soldiers of a great warrior.

In his mathematical physics lectures—aye, even in his elementary lectures—the suggestions that he poured forth were much above the heads of the ordinary undergraduates—over 100 in this class—and they gained little by coming to them except a register of their attendance, necessary for their degrees. For, as soon as he turned round to write on the blackboard, the students row by row began to creep out of the lecture room through a back door behind the benches and steal down-stairs, their bodily presence following their mental presence, which had left as soon as the reading of the roll-call was finished. From time to time Thomson put up his eye-glass, peered at the growing empty space, and remarked on the curious gradual diminution of *density* in the upper part of the lecture room.

This class consisted mainly of divinity, medical and law students, who, of course, should have been taught the elements of natural philosophy by some assistant provided by the university. To waste the time, energy and extraordinary original power of a genius like Thomson on such teaching was like using a razor to chop firewood. The junior clerks in Downing Street require instruction, but the prime minister is not expected to personally hold daily classes for them. And yet, during the past eighty years, there have been many prime ministers, but only one William Thomson.

But to those, like myself, who, after receiving some scientific training, had come from other countries to hear Thomson's talks, his suggestions, his buoyancy, were like the rays of brilliant May sunshine following April showers. The ideas of those students sprouted as never had they done before. The more thoughful gazed with eyes of wonder at Thomson developing an original paper during a lecture on anything that he might be talking about, we knowing that any notes or calculations that he might previously have made were on the back of some old envelope and left probably with his great-coat in the hall. "If you want to know what's in books go and read them for yourselves. I am telling you what is *not* in books," he used to remark at those lectures at the old University of Glasgow (now a railway goods station), the "Academia Glasgnana," founded by a bull of Pope Nicholas V., and built on the east side of the High Street in 1450 under the authority of Gulielmus Turnbull, Bishop of Glasgow.

The present university did not exist in my student days; in fact the classic stream Kelvin, although beginning to show signs of the drainage from manufactories spreading to the northwest of the city, flowed through a park and a dale still of a sufficiently sylvan character to make the words of the old song, "Oh! let us haste to Kelvin grove," not absolutely inapplicable.

To my question, "What books on electricity shall I read?" he replied "None! there are none. But you might read some of my papers in the *Philosophical Magazine*." Clerk Maxwell's classical treatise, Fleeming Jenkin's "Electricity and Magnetism," and the reprint of Thomson's own papers did not appear until some years afterwards. Fleeming Jenkin, who with Cromwell Varley became a partner in that famous firm of consulting telegraph engineers, "Thomson, Varley and Jenkin," was the first person to write a text-book which brought together disconnected and disjointed experiments and gave the elementary mathematical theory underlying them. In the preface of this book, which first appeared in 1873, the author said:

> In England at the present time it may almost be said there are two sciences of electricity—one that is taught in the ordinary text-books, and the other a sort of floating science known more or less perfectly to practical electricians and expressed in a fragmentary manner in papers by Faraday, Thomson, Max-

well, Joule, Siemens, Matthiessen, Clark, Varley, Culley and others. The science of the schools is so dissimilar from that of the practical electrician that it has been quite impossible to give students any sufficient, or even approximately sufficient, text-book. . . . A student might have mastered Delarive's large and valuable treatise, and yet feel as if in an unknown country and listening to an unknown tongue in the company of practical men. It is also not a little curious that the science known to the practical men was, so to speak, far more scientific than the science of the text-books.

Among Thomson's early discoveries was the fact that it was good for students to do laboratory work. So almost immediately he was appointed the professor of physics, at Glasgow, in 1846, at the age of twenty-two, he "organized a laboratory corps from volunteer students," and about 1849 he "established an incipient laboratory in the wine cellar of an old professor's house," so his successor, Professor A. Gray, tells me. In my time Thomson's laboratory consisted of one room and the adjoining coal cellar, the latter being the birthplace of the syphon-recorder. To avoid friction with the capillary glass syphon, which was moved to the right or left by the electric signals coming through the submarine cable, the end of the syphon was not allowed to touch the strip of paper, but a continuous stream of ink spurted out of the syphon on to this paper in consequence of the reservoir of ink, into which the other end of the syphon dipped, being kept highly electrified.

To find out what sort of electrical machine should be used for this purpose Thomson suggested that we should measure the efficiency of frictional electric machines. We did so, and brought him the result —viz., efficiency equals some small fraction of unity. He replied, "I can not degrade a man by asking him to use his energy so wastefully; I must design something better." And he did—viz., the influence machine; then when, by carrying out his suggestions, a fellow student and I had constructed an influence machine and got it to work, he sent us to the Glasgow Patent Office to see whether any one had thought of that principle before. And we found Varley's and other anticipations, with, however, this difference—that the earlier patentees proposed giving to the arrangement an initial charge to start its action, whereas Thomson's was a machine that worked on the compound interest law, starting with an infinitely small initial capital. This led not only to the "mouse mill" and the "replenisher," but to the class working all kinds of problems on investments at compound interest. "Now, suppose the interest is one one-thousandth per cent., paid every one one-hundredth of a second, etc.," and we who had never invested any money in our lives, indeed, possessed no money to invest, might have been mistaken for budding pupils of a stock broker had any visitor chanced to come into the lecture room.

There was no special apparatus for students' use in the laboratory, no contrivances such as would to-day be found in any polytechnic, no laboratory course, no special hours for the students to attend, no assistants to supervise or explain, no marks given for laboratory work, no workshop and even no fee to be paid. But the six or eight students who worked in that laboratory felt that the *entrée* was a great privilege. College laboratories for any branch of physics did not, as far as I remember, exist anywhere in London during my student days. Principal Carey Foster started one in 1866 shortly after his appointment as professor of physics at University College, since he realized that making experiments was as great a necessity for students of physics as for students of chemistry. And it was Carey Foster's pioneering efforts to have a students' physical laboratory at University College, and his description of what Thomson had done at Glasgow, which made my mouth water and turned my attention northwards. Of course, the accommodation in Gower Street for physical work in 1866 did not differ much from what had existed at Glasgow since 1846, and certainly even in 1879, thirteen years later, Professor Cornu's students at the Ecole Polytechnique, Paris, never touched a piece of physical apparatus, although the *cabinet de physique* there contained all the originals of Regnault's classical apparatus, or facsimiles of the apparatus that Regnault had used in his investigations.

Thomson's students experimented in his one room and the adjoining coal cellar, in spite of the atmosphere of coal dust, which settled on everything, produced by a boy coming periodically to shovel up coal for the fires. If for some test a student wanted a resistance coil, or a Wheatstone's bridge, he had to find some wire, wind the coil, and adjust it for himself.

It is difficult to make the electrical student of to-day realize what were the difficulties, but what also were the splendid compensating advantages of the electrical students under Thomson in the sixties. We were like a band of emigrants following our leader in wagons across the prairies and the Rockies on the way into California in 1848. While his far greater genius, perseverance, and endurance would enable him to find nuggets, we perhaps might find specks of scientific gold. We were proud to follow him, we did not expect or even know what the laboratory luxuries of to-day would be, we did not need an Empire State Express train to hurry us in Pullman cars along a line of smooth level rails.

If the instrument given us by Thomson to work with had never been described to us—if its theory or even its use was entirely unknown to us—well, there were no maps for the early emigrants going westward to fall back on, they had to ford the streams for themselves, and did not expect to find bridges already built to enable them to step over every difficulty.

The fact that the students of to-day have such a wealth of apparatus at their hands, printed instructions supplied them, text-books galore, has made them globe-trotters in the region of science. They lack the self-reliance, the initiative to devise expedients for accomplishing ends which the emigrant pioneers in science fifty years ago had to employ. Indeed, it is becoming a question whether using a dictionary to translate a Latin or Greek play is not a better training for the inquiring faculty than working in a modern physical laboratory, since at any rate the translator has to use some thought.

Thomson openly expressed his contempt for a university that spent its time merely in holding examinations, as did the Burlington House University of London at that time. One day I was in his lecture room puzzling over an examination paper that he had set, when he advised me to take the paper home to my lodgings, as I should be much more comfortable there. Such a permission was an upheaval of all my ideas about scholarship examinations; so, boy like, I asked him how he would know that I should not look at books. But he only replied, "When you bring me your answers to-morrow I shall know what you have got out of books." I expect he sent me to my lodgings partly to impress on me the important lesson that all the books that exist will not solve a new problem.

The incident left a deep, lasting impression on me, partly because at the public announcement of the examination results he referred to his method, and jokingly ended with the remark: "This course was on hydrodynamics, and when we got into deep water there was only one student who was still in his depth." What a young engineer can do, using all existing knowledge, is, of course, what an examiner should try to test, *not* what the examinee can remember and reproduce.

He had great belief that one of the main uses of a university was to form character. He, Rankine, Tait and some other professors had a long discussion in his house one evening after dinner. Would he have been justified in asking that the student who had that day thrown a paper dart at the blackboard when he himself was writing on it should declare himself. Thomson thought no! As a matter of fact the student owned up. He was asked to absent himself from the class, but, on the other students pointing out that he would lose his degree by not attending, Thomson readmitted him.

Thomson always began his nine-o'clock lecture by devoutly repeating the General Confession from the Church of England Morning Service. I do not know whether the other Glasgow professors did. There was never the slightest interruption; the Scotch student is naturally reverent, besides, the prayer was said by Thomson with such fervor and impressiveness that the most stanch freethinker, the most frisky dart-thrower, could not but respect the convictions of the teacher whom they all loved and honored. They might not be able to follow the lecture; but the affecting appeal which preceded it touched their hearts.

When he described to us how Joule in 1840 had experimentally proved that the rate of production of heat was directly proportional to the *square* of the electric current, and not to the first power, he used to add, "And Joule had the honor to have his paper rejected by the Royal Society. For it *was* an honor in those days." The rejection of the results of experimental work, although scrupulously accurate, because the experimenter was not already well known, filled Thomson with indignation. For example, the assertion of Sir William Snow Harris (*Phil. Trans.*, Roy. Soc., 1834, p. 225) that the heating power of electricity was *simply* as the charge, as well as many other electrical errors which Thomson used to dilate on, was held up to scorn before the class as "fashion *versus* truth in science." In the *Philosophical Magazine* for 1851 Thomson published an article explaining and defending Joule's work on the heating of conductors.

This ability to sift the wheat from the chaff, the courage to champion what he believed to be true, even if it were not the fashion, and the readiness to give up a theory when speculation lacked accurate experimental corroboration were marked features in Thomson's character.

During the sixties the world was very much interested in the possibility of an Atlantic cable. The 1857 cable had broken while being laid; the 1858 one had failed after one short month of existence; the 1865 cable snapped after 1,186 miles had been laid, and, although nine days were spent in trying to pick it up, and, although it was grappled many times, the rope broke; and this cable, like its predecessors, had to be abandoned. A few yards of this 1865 cable that had been picked up lay on the floor of the Glasgow laboratory and was often pointed to by Thomson as being what had given them heart and kept off despair. Then a prize of over three quarters of a million sterling was offered to the Telegraph Construction and Maintenance Company if they could complete the 1865 cable and lay an 1866 one. And they won it.

While it was remaining doubtful whether the two sides of the Atlantic would ever be coupled electrically, Thomson's secretary not unfrequently used to be sent to the Glasgow railway station a few minutes before the mail train started with this urgent message from Thomson: "I have gone to White's to hurry on an instrument. The London mail train must on no account start to-night until I come." And such was the national importance of the problem, and such the honor in which Thomson was held, that the station-master obeyed.

Many have used a Thomson's reflecting galvanometer and have regarded it merely as an extremely sensitive galvanometer without knowing how it came into existence. It was devised by Thomson to enable him to utilize his mathematical solution of signaling through a long submarine cable, and was regarded of such national importance that a private act of Parliament was sanctioned by the Privy Council to extend the normal life of fourteen years for the patent of this cable "speaking instrument," as it was originally called. The invention of this instrument marks the theoretical solution of a most important problem, which solution Thomson found great difficulty in getting the electrician of that day to accept.

As early as 1855—before any long submarine cable had been constructed—Thomson published in the *Proceedings of the Royal Society* the theory of the propagation of signals through a cable based on a correspondence which he had had with the late Sir Gabriel Stokes, and he showed that the book "Fourier de la Chaleur"—that "mathematical poem," as he used to call it—contained, in Fourier's mathematical equations of the flow of heat, the entire mathematical solution of the propagation of electric waves through a cable. From "Fourier's series" he deduced that, whereas on a short overhead telegraph line the signal reaches its full strength at the distant end practically as soon as the signaler at the near end of the line begins to send it, with a submarine cable it is retarded, spreads out, and blurs the next signal. There is a past history effect as in politics and in many natural phenomena. The passing of an act of Parliament can not suddenly change a people; indeed, it is well known that the actual effect of an act of Parliament promoted by well-wishers is often gradually found to be most harmful, and has to be repealed or curbed in its action.

Herbert Spencer in his "Sociology" strongly advocated legislators to study the science of politics. Thomson would perhaps have said, "Study Fourier's mathematical poem."

If it were attempted to send a series of electric signals through an Atlantic cable with the *same* apparatus and at the *same* speed as messages are sent between London and Brighton, the signaler at the far end would not have the slightest knowledge that the signaler at this end was trying to send a message, whatever were the strength of the current sent into the cable. To work a long submarine cable, either time must be allowed for each signal to grow at the distant end, or, as this would make the sending of messages very slow, the receiving instrument and the signaler receiving the message must, like a clever doctor diagnosing a disease, be able to interpret mere indications. Sending the letter "e," for example, produces at the other end of a long cable a totally different result, depending on what has preceded it. In no case, at a speed of, say, thirty words a minute with a 3,000-mile cable, will it be more than a suggestion, even at the beginning of a word; but in the syllable "toe" the "e" is as indistinct as the hurriedly written scrawl that you are very glad to get some one else to read for you.

Thomson wanted a receiving instrument which, unlike the ordinary telegraph instruments used in post-offices and railway stations, could render the interpretation of such suggestions possible in the hands of an expert signaler, and he devised the mirror galvanometer speaking instrument to obtain this result.

Another most important fact that his theoretical investigation brought out was that no increase of battery power could counteract the retardation in the signals produced by an impurity existing in the copper conductor of a cable, and hence that every yard of copper wire used in the thousands of miles of a long cable must be electrically tested for resistance before being used.

But all this appeared to the electrician as arising from the ignorance of an inexperienced young man who had never erected a mile of telegraph line in his life, and would not have been given a job in any telegraph office. And so when signals through the 1858 Atlantic cable became weak, and a message from the president to our queen took thirty hours in transmission, although containing only 150 words, and which would need only three or four minutes to transmit through any one of the good Atlantic cables of to-day, the only remedy of those who looked down on the theories of the young Glasgow professor was to use Whitehouse's "thunder pump," a magneto-electric machine which produced a sudden large electromotive force when the armature of the permanent magnet was jerked off the poles of the magnet. But these shocks only sent sparks through the gutta-percha insulating coating and hurried the poor cable to its doom, so that even the three words per minute which would have been the utmost limit of speed possible had this cable been entirely uninjured, were replaced by absolute silence.

But Thomson energetically struggled on and, pursuing (as he told me afterwards) a "Parnell-Biggar policy" at the board meetings of the Atlantic Cable Company, obstructed all business until the directors promised to have all the copper wire tested for resistance before being made into cable; and thanks to Thomson for his theory of signaling, to that engineer of energy and surprising resource, even when quite a lad, Sir Charles Bright, to Captain Anderson of the *Great Eastern*, and to all those who have followed in the history of submarine cable development the London Stock Exchange is by cable to-day within thirty seconds of Wall Street.

Thomson's work in connection with submarine telegraphy has been epoch-making. But thirty-three years ago it was associated with what I felt was a national loss. I give it in an extract from a long letter which he wrote to me in Japan, December, 1874: "My dear Ayrton—You will be very sorry to learn of the terrible loss which has befallen us in the loss of *La Plata,* cable ship, with my nephew David King on board. . . ." David King and I had worked together for Thomson. I had seen them much in company with one another. In appearance, independence of thought, and in many ways there was great resemblance between uncle and nephew, so that I used to hope that a corner of the mantle of William Thomson might rest on David King.

Thomson has been called an engineer. In creative power, yes—a great engineer. But not in the forties, nay, even in the sixties, could a university student at either London, Glasgow or Cambridge learn what to-day is called even college engineering. Thomson had never learned to make a working drawing; he designed in metal. We students could not help him with the T square and drawing-board as we might have done had we received the college engineering training of to-day. He thought of a new instrument, a new method of accomplishing some result flashed on him, and he sketched in his pocket-book a rough indication of what he wanted constructed; I took the idea, or what I understood of it, in my head to Messrs. White, so it was not to be wondered at that alteration after alteration was necessary before the thing that was in Thomson's mind's-eye became realized in metal.

But oh! the delight of those days! Would we have exchanged them, had the choice been given us, for days passed in the most perfectly designed laboratory of the twentieth century without him? No! for the inspiration of our lives would have been wanting. As pathetically said, since his death, in the *Electrical Review,* "Le roi est mort," but we can not add, "Vive le roi," for were the whole world summoned, "no successor would there be."

MAN'S EDUCATIONAL RECONSTRUCTION OF NATURE

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THE purpose of education among those animals that train their young is adaptation to environment. Man's endeavor is the same, but with the growth of human society and of knowledge his environment has profoundly altered, a fact that education has only partially recognized, and this alteration has made it necessary to reinterpret adaptation. Among the lower animals, nature secures the necessary results mainly through instinct.

Jennings found[1] that paramecia collect around a mass of bacteria, pushing and crowding one another in apparent effort to reach the food, and Binet,[2] in one of those delightful, imaginative flights in which even the scientific mind at times is wont to recreate, would have us believe that most, if not all of the higher intellectual processes, including choice and volition, form part of the mental life of micro-organisms. But we are clearly drawing inferences beyond our right if we assume that action here has any other cause than the necessity which selection has made the conditions of survival. These organisms must do certain things and do them *always,* under penalty of extinction, and perhaps this is the reason why these same paramecia begin to gather around innutritious substances quite as surely as around nutritious. The attraction which a dilute solution of carbon dioxide has for them would then, as Jennings has suggested, be due to the fact that this product of organic waste is found wherever paramecia assemble; therefore, as they gather more often than otherwise around food and natural selection demands that they lose no chance of finding nutriment, carbon dioxide becomes a blind call to food. Instinct is thus organic behavior originating in the necessity of adaptation and directed in its course through the exigencies of the environment by natural selection. Whitman[3] has observed that our fresh-water salamander, *Necturus,* reacts to any object quietly introduced into the water, as though it were food. If so small an object as a needle, he says, be brought into contact with the surface of the water, *Necturus* instantly turns toward it. The reason is that the animal receives exactly the same stimuli from a foreign object that touches or passes through the water as it does from

[1] "Psychology of a Protozoan," *Am. Jour. of Psychology,* Vol. X., 1899, p. 503.

[2] Binet, "The Psychic Life of Micro-organisms," 1899, p. 61.

[3] "Biological Lectures from the Marine Laboratory at Woods Hole, Massachusetts," 1898, p. 303.

that which serves as food. In other words the animal responds primarily to water undulations, regardless of their cause, because it is through such undulations that it receives notice of the presence of food. In its most typical form instinct is thus seen to be chiefly a matter of animal organization, and the response to stimuli to be largely mechanical. This makes stable conditions necessary if it is to meet educational needs. But even here there is a little variation in the manner of reaction. *Necturus* has learned to discriminate somewhat between experiences, for, according to Whitman, "there is unmistakably a power of inhibition strong enough to counteract the strongest motive to act—the hunger of a starving animal in the presence of food."[4] But such limited power of reaction does not go far, and it will meet the needs of animals only so long as their life is of the simplest sort. They are probably capable of few adaptations, and these must be made at an enormous cost of time and life. But as life becomes more complex and less regular these instinctive responses do not answer. Animals must now learn to remember, and their actions must be guided by past experiences of threatening disaster, else they can not survive in the struggle.

Not many experiments have been made on the educability of animals low in the scale, but fishes have been taught to refrain from attacking minnows that are their usual food, by separating them with a glass partition extending across the aquarium until the larger fishes learn by repeated bumps on the nose that the little ones are not to be eaten.[5] Thorndike[6] has shown also that the minnow, *Fundulus,* can learn to find its way through a series of three partitions, each with an opening so located as to make the journey circuitous, and that it gradually improves on its previous record by eliminating blunders until finally it learns to go directly to each opening. While we do not know much about the mental processes here, it grows increasingly harder to explain action solely by the neural mechanism. Experience is evidently taking a more active part in the animal's life. The nervous system is becoming more flexible, more adaptable.

Recent observation has somewhat modified our views regarding action among lower animals. Jennings's studies[7] indicate that the method of trial and error is common even in one-celled organisms. This method, wherever found, unquestionably involves in some degree the utilization of experience. Such creatures can no longer be considered as merely reflex organisms in the presence of new needs and

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[4] *Loc. cit.*, p. 305.

[5] See statement of Moebius's experiment in Darwin's "Descent of Man," second edition, p. 76, and Triplett's "The Educability of the Perch," *Am. Journal of Psychology*, Vol. 12, p. 354.

[6] *Am. Naturalist*, Vol. 33, p. 923.

[7] "Contributions to the Study of the Behavior of Lower Organisms," p. 237; Carnegie Institution, Washington, 1904. "Behavior of Lower Organisms," 1906.

difficulties, or, if we still designate their action in this way, the interpretation of "reflex" must be profoundly altered. Throughout the animal series improvement in the reaction to environment seems to signify greater nervous flexibility in dealing with experience rather than a complete change of method. In their fascinating paper[8] on the habits of solitary wasps, the Peckhams tell of one who in filling up her nest "put her head down into it and bit away the loose earth from the sides, letting it fall to the bottom of the burrow, and then, after a quantity had accumulated, jammed it down with her head. She then brought earth from the outside and passed it in, afterwards biting more from the sides. When, at last, the filling was level with the ground, she brought a quantity of fine grains of dirt to the spot and, picking up a small pebble with her mandibles, used it as a hammer, pounding them down with rapid strokes, thus making this spot as hard and firm as the surrounding surface." Soon "she had dropped her stone and was bringing more earth,"[9] when she again picked up the pebble and pounded that which was brought until all was hard.

The power to inhibit, so that the same action does not always follow the same stimulus under the same circumstances, which was observed in *Necturus,* indicates, perhaps, the first break in the mechanism of primitive instincts. The part that experience plays in the animal's life is becoming more immediate and direct. Just how much consciousness is involved in this, or, indeed, whether there is any, we do not know. Investigation has shown[10] that in man consciousness of means is not essential to the utilization of experience and there is certainly no reason for thinking it more necessary to the lower animals.

In the variability of instinct, also, we find mechanical organization less domineering, and in the study of wasps, to which we have just referred, the one preeminent, unmistakable and ever-present fact is variability. "Variability in every particular—in the shape of the nest and the manner of digging it, in the condition of the nest (whether closed or open) when left temporarily, in the method of stinging their prey, in the degree of malaxation, in the manner of carrying the victim, in the way of closing the nest, and last, and most important of all, in the condition produced in the victims of the stinging," some of them dying "long before the larva is ready to begin on them, while others live long past the time at which they would have been attacked and destroyed" had not the investigation "interfered

[8] "On the Instincts and Habits of the Solitary Wasps," by Geo. W. and Elizabeth G. Peckham, Wisconsin Geological and Natural History Survey, Bulletin No. 2, Scientific Series No. 1, Madison, Wis., 1898.

[9] *Loc. cit.*, pp. 22–23.

[10] Swift, "The Psychology of Learning," *Am. Jour. of Psychology,* Vol. 14, p. 217.

[11] *Loc. cit.*, p. 30.

with the natural course of events."[11] In this breaking away from the inherited way of doing things we seem to have a sort of organic initiative which, if we may not call it intelligence, must, after all, develop into it.

Observations on higher animals have been numerous, and Darwin quotes with approval a statement of Rengger that when he first gave eggs to his monkeys in Paraguay, "they smashed them, and thus lost much of their contents; afterwards they gently hit one end against some hard body, and picked off the bits of shell with their fingers."[12] Kinnaman,[13] in his extended study of the intelligence of two monkeys, found that they could learn to manipulate a complex series of locks and latches on a box, and that they made some progress in choosing better methods by eliminating useless acts and in making short cuts. He also tested men with the same apparatus and found that some were slower than the monkeys in finding how to open the box. While there was no evidence of ability to count, one of the monkeys could recognize position as far as three and the other as far as six.

All this is a clear advance on the mental processes of lower forms, which can not be explained solely by the mechanical response of a better organized nervous system. The change from the animal's customary behavior is too great and the variations too sudden for mechanical organization to account for them. And yet Kinnaman's report shows little method in it all. The monkeys knew enough to know when they had failed, which is more than can be said of the fishes until it has been battered into their nervous system through repeated blows on their heads, and they gradually improved on their method by making short cuts. But Thorndike's fishes also showed this improvement, though much more slowly. And this seems to mark an important difference in mental life. Monkeys do not need to wait until a certain mode of behavior has been worked into the mechanism of their organism by the operation of natural selection, as do paramecia, nor is it necessary that the external constraint, which encourages inhibition, be continued for so long a time as in the case of fishes. But, after all, the reasoning of monkeys seems to be of the same associative sort as that of fishes, and there is certainly no convincing evidence that they are able to get beyond this. Kinnaman thought that their action indicated generic images which enabled them to carry over something from a previous experience to a new situation, but we have already seen that even in man consciousness of the process is not necessary to the utilization of experience and it is difficult to see what a generic image of which we are unconscious could be. Indeed, on the theory of evolution, consciousness as an originating force in the learning process would seem to be much less necessary to the

[12] "Descent of Man," second edition, p. 78.

[13] *Am. Jour. of Psychology*, Vol. 13, pp. 98 and 173.

lower animals than to man, and the farther down the series we go the less important would it become, until, among micro-organisms, we can not speak of conscious adaptation without greatly overstepping the bounds of scientific accuracy. So far as the evidence goes, learning among the lower animals is strictly a matter of association. The more intelligent of them appreciate the failure of a method quicker than the others, and the discomfort resulting from it exerts a depressant effect upon the whole neuro-muscular system which tends to break up the incipient coordinations which were involved in the original action, and even to obliterate their neural effects. All this, of course, reacts against repetition. Success, on the other hand, is attended by a pleasurable feeling, and every one has observed the joyous look of animals capable of expressing their emotions, when they have accomplished what they have been trying to do. These pleasurable feelings increase the muscular tonicity which always tends to motor discharge, and this results in a partial reinervation of the coordinated group of muscles that were involved in the original movement. This naturally deepens the existing neural effect and tends to the repetition of the movement that occasioned it.

So far as our present state of knowledge permits us to draw conclusions, the intellectual difference between man and the lower animals consists primarily in just this difference between associative reasoning on the one hand, and, on the other, inference in which the connection is obscured, by time or space, or by the complexity of the elements involved. And here, as before, the part that experience plays in determining action is the measure of intellect, only now its influence has been enormously multiplied. Articulate speech has enabled man to organize his experiences and transmit what he has learned, and it is not improbable that the higher psychical processes involved in reasoning owe to this human acquisition their development if not their origin. Speech has greatly accelerated adaptation—by no means an unimportant factor in the rapid changes of man's experience, since through it we learn from others that which may benefit or injure, and so avoid what might mean destruction of the species. And then, too, by enlarging the sum of the experiences it has greatly increased the facility in acquisition and assimilation which plays so important a rôle in human progress.

Learning in man, whether it be a new adaptation to a changed situation or the acceptance of an intellectual truth or moral principle, depends much upon the content of the individual mind, and this assumes infinitely greater importance in man than in the lower animals because of the immense complication of his environment. With animals this content embraces at most relation to the physical world and to other animals, but with man the physical world means and includes much more. It grows until it embraces the universe, and the relation to others widens until, from a simple physical relation, it involves the action of men on the highest plane of consciousness. Education in man is to fit his offspring for all this—for the most perfect attainable life in this complicated and ever-growing physical and psychical environment. We have to educate for an essentially new universe and the demand for studies that will be directly useful in life, now becoming so energetic, while one strong expression of the growing consciousness of this need is yet an utterly inadequate expression of it.

Clearly, education through instinct, nature's way, becomes then wholly insufficient for man. Its method of adaptation is too slow when physical and psychical conditions change so rapidly. Besides, it costs enormously. The herring lays twenty thousand eggs, the oyster upwards of sixteen million, while the conger-eel requires the enormous number of fifteen million annually to save itself from annihilation.[14] Marshall and Brooks estimate that if you start with one oyster producing sixteen million eggs, half of which are females, and let them go on increasing at the same rate for five years, there would be oysters enough, if we estimate them as shells, to make a mass more than eight times the size of the earth.[15] As we descend the animal series these facts become still more startling. "Certain bacteria multiply so rapidly that the descendants of a single individual, if allowed to multiply unhindered for three days, would be represented by the figures 47,000,000,000,000."[16]

Among lower animals the individual is of little importance because infinite numbers can be produced, and the cost does not matter much, but in the human world the individual has become of supreme importance. It is costly to vitality to bring even one to maturity and expensive in every way to train him. Besides, the worth of a human being is recognized as permanent. A fine individual is of the highest value to the whole. The best are pioneers to a higher level. Fine individuals create a good society, and a superior society, in turn, is a prime factor in the production of the finest individuals.

With the lower animals the purpose is adaptation to environment, a strictly biological end, but the growth of knowledge and culture has introduced a higher element into human society which adaptation can not fully satisfy. This is that man must always improve his environment. Character is not merely a matter of heredity, but of heredity acted upon by environment. This is illustrated, on the one side, by the Juke family, and on the other by the transformation wrought in boys of

[14] C. J. Marshall, "Lectures on the Darwinian Theory," New York, 1900, p. 39.

[15] *Loc. cit.*, pp. 39–40; W. K. Brooks, "The Oyster," p. 50.

[16] H. W. Conn, "The Method of Evolution," p. 53.

criminal parents when placed in good surroundings. Many are convinced that the elimination of those in whom the anti-moral tendencies are strong is essential for moral evolution, and this is certainly nature's method, as she deals summarily with animals whose actions are at variance with the immediate good of the species. But human progress is not so simple, its problems are not so easy of solution. Discrimination is necessary in order to know what are the anti-moral proclivities. Seemingly reversionary tendencies in early life, for example, are not always bad, since many times they are the source of our best social strength and virtues. The so-called criminal instincts of children are survivals of acts that among primitive races fitted their possessors to survive. Deception and the strength and willingness to fight well, and to kill, were essential to racial existence, and these were the highest virtues of which primitive man could conceive. To-day these acts are wrong in adults because they are not only unnecessary, but hinder progress. They do not fit man's reconstructed nature. They are anti-social. Yet the elimination of boys with these anti-moral characteristics would be fatal. Altruism arose as a kind of enlarged egoism. At first man must have been chiefly, if not wholly, individualistic, but very soon a time came when individual selfishness no longer served its egoistic ends, and self preservation required the extension of each self to embrace all members of the tribe. Self interest thus became absorbed in tribal interest, not at first because of any moral ideas about the rights of others, but solely because in this way each one's self-interests were better served. But these primitive instincts are not without meaning for modern life. The readiness of civilized boys to fight shows an independent, active, aggressive character which, rightly guided, leads to manly courage. The determined opponent of civic corruption, the man whose onslaughts no threats can stay, was a boy who fought for boy's rights. The prevailing social ideas are important in giving these tendencies the direction that makes for progress, and their very persistence and vigor is a necessary element in evolution.

The power of ideas and actions when intelligently applied to conduct has been shown in the complete change of life of the New York City toughs who were given the ideals and ambitions of the George Junior Republic. In the slums of the city their racial tendencies followed the drift of excitement and adventure natural to a criminal environment, but with the social suggestions and inspirations of the republic these instincts found new outlets which led to manhood under civilization, while still satisfying the organic yearnings of the race. The evolutional impulse in all this is an atmosphere of moral thoughts and actions, but we must take care not to confuse mere custom or tradition with morality.

Animals are dependent upon conditions in the selection of which they had no part. Theirs is merely to adapt. Man, on the other hand, may assist in bringing about conditions amid which the next generation will live. As adaptation is as much a human as an animal characteristic, the importance of the environment becomes evident, especially when we remember that in man no less than in the lower animals those qualities are selected for survival that best fit the conditions. Alfred Russel Wallace has given a splendld illustration of this in his "Malay Archipelago." He wrote:

> There are now nearly five hundred people in Dobbo, of various races, all met in this remote corner of the east, as they express it, "to look for their fortune," to get money any way they can. They are most of them people who have the very worst reputation for honesty, as well as every other form of morality—Chinese, Bugis, Ceramese, and half-caste Javanese, with a sprinkling of half-wild Papuans from Timor, Babber and other islands—yet all goes as yet very quietly. This motley, ignorant, blood-thirsty, thievish population live here without the shadow of a government, with no police, no court and no lawyers; yet they do not cut each other's throats, do not plunder each other night and day, do not fall into the anarchy such a state of things might be supposed to lead to. It is very extraordinary! . . . Trade is the magic that keeps all at peace and unites these discordant elements into a well-behaved community.[17]

The power to modify environment gives man possibilities not possessed by any of the other animals, but it adds vastly to his social responsibility in education. The environment is put upon the lower animals as it were from overhead, and they are left no choice but adaptation or extinction, but man may make his own environment, and in this way break a trail for progress.

The difficulty in applying the principle of natural selection to education is that we do not intelligently determine who are the fittest. In nature the conditions demanding adaptation are comparatively simple and definite. This is true also of primitive man, and, indeed, quite largely of early civilized society. But the enormous enlargement of human interests dims our vision. In one respect the lower animals have the advantage of us in their instinctive educational methods. Their teachers are never troubled by doubts concerning the ability of their pupils. All receive equally careful training for life. They do not prejudice the future of any by an adverse verdict so early in life that the best in them may not yet have appeared. They train all in the best way for success, which in their case means survival, and then leave the final decision to natural selection. The conclusion of one of England's foremost statisticians that the senior wrangler has twenty-five times the innate ability of the lowest on the honor list, because in one year the former obtained 7,500 credits to 300 of the latter, is one of the humorous results of the so-called scientific method of investigation. Against the hallucination of such measurements let us remember that Darwin's father prognosticated that he would disgrace his family because he cared for nothing but shooting, rat-

[17] *Loc. cit.*, p. 443.

catching and dogs, that Harriet Martineau was a dull child, and Seward "too stupid to learn," that Isaac Newton at twelve led his class at the foot, that Samuel Johnson was lazy, Robert Fulton a dullard, Oliver Goldsmith insufferably dull in his teacher's opinion, Byron lowest in his studies, Richard Sheridan insignificant as his teacher saw him, John Hunter slow and late to learn, Linnæus, in view of his stupidity, recommended by his pedagogue to be a cobbler, and that Dean Swift through "dullness and insufficiency," and Goethe likewise from seeming inability, forfeited their degrees.

It is not to be forgotten that the survival of the fittest is always relative to the conditions demanding adaptation and, while animals have no preference, man may exercise a choice as to the conditions to which he will adapt himself, and this is broadly the distinctively human quality. The cleverest boys in the slums of New York become the most skillful thieves. In the George Junior Republic, as we have seen, the same boys grow into the best citizens. Here environment is created and chosen by society for the boys; where it appoints them to a slum environment it produces thieves and criminals; where it gives them a rational environment out of the same material it produces first-class types.

Now society may fail to choose for itself the highest goal, which is nothing but failure to select the largest environment to which to adapt itself. It has choice of various inferior lines of growth. Then "practical" education will aim to fit the individual for most perfect adaptation to the inferior plane chosen. *Man has largely inherited the animal method and only partly adopted the human.* Nature has provided education for animals only in a state of stability. For change, improvement, nature has provided animals with nothing that can be called a method, for the means it uses is destruction—destruction for all who do not conform to the needs of the change, and in working out a new adaptation, the destruction of all who stray extends over an immense period before a new state of stability is established with a new instinct to conserve it. Now this is an incredibly blundering and costly method where the individual is of any account and where the goal is of value, both of which conditions are true of man. It meets the need of animals because survival is the only thing aimed at and the "fittest" are those adapted to the prevailing conditions. The inadequacy of the principle for man and education becomes evident since the conditions demanding adaptation, if ethically low, will call for and bring out men of an inferior type and in a society of this kind the few that might seek to make their adaptation to a more universal environment, though they would be the best from the standpoint of civilization and progress, would be suppressed. But the society choosing this principle stagnates and, in the long run, retrogrades. Now the purpose of education should not be merely to fit each generation for adaptation to the grade that society may happen to hold at that time, but to create in men the habit of discriminating and of choosing that which leads to something higher.

The importance of this point of view is not lessened even if it be shown that natural selection is not the only force operative in producing change. New characteristics may appear suddenly, so-called mutations, but their persistence is after all dependent upon the environment. True, they may persist without being of immediate advantage, but only when conditions are not too unfavorable. Here, again, it should be the purpose of an intelligently endowed society to make conditions that will preserve incipient and less stable individual variations that have appeared, according to the supposition, through no direct environmental influence, but which may tend toward a higher social organization. It is not enough that conditions permit the survival of such varieties under difficulties; they should favor their continuance. While some "mutations" may exist under conditions not altogether favorable, others will require social recognition and society should see to it that the persistence of such sensitive "mutations" is not too hazardous. In this way a tendency to vary, a characteristic which means much for progress, may be fostered. In his work with plants Vilmorin found, according to Darwin, that "when any particular variation is desired, the first step is to get the plant to vary in any manner whatever, and to go on selecting the most variable individuals, even though they vary in the wrong direction, for the fixed character of the species being once broken, the desired variation will sooner or later appear," and Burbank has recently made the same observation.

Among lower animals variation facilitates new adaptations, but in man it has assumed an added function, that of suggesting new departures, new lines of progress, and in doing this it makes important contributions to the growth of experience. Education is always in danger of arrest from compression by immediate or "practical" aims. It should be of a sort that admits of indefinite expansion so that in the end it may become commensurate with life; but this capacity for enlargement requires something more than knowledge. Inability to see this led to the fallacy of the educational system of the middle ages; and we have fallen heir to their infatuation for formal training and learning. Information did fairly well for the simple conditions of early times when the necessary adaptations of life were neither complicated nor numerous, but if education is to be adequate to the life of to-day it must take the whole plexus of social forces into account and these social forces are, after all, only biological principles working in human society, to be intelligently interpreted and used for the greater life of society.

One of the elements in progress, and by no means an unimportant one, is that of which we have just been speaking, and which we may call suggestive variation. The world is moving with constantly accelerated velocity, not merely because we have more information to-day than yesterday, but because what we know means more to us, and this alchemistic power of getting out of facts something not superficially visible in them is mind's contribution to progress. Now education has never appreciated the importance of variation in human society and for that reason has never set itself to develop it. The very capacity for variation, implying as it does a certain flexibility, facilitates ready adaptation in the individual, and its suggestive influence on society promotes adaptation in others. The means, of course, by which this influence becomes effective is speaking and writing. The function of education here is to develop a mental attitude that is friendly to variation, and to train to rightly see and interpret relations. There seems to be an impression that if we just give a child or a man information enough he will at some time and in some way—though we are never told just when or how—learn to apply it to the problems of life. But the facts do not justify this view. The astonishing velocity with which science and industry are moving to-day calls for correspondingly rapid adjustment, and owing to defective principles of education we are unable to meet the demand. This is the reason for the conflict between labor and capital. Industry has advanced so fast that instinctive society could not keep up with it. Not educated to vary flexibly we can not adjust ourselves in time to new conditions. We are confused and baffled by them. The intellectual element enters into human adaptations, and the more rapid the change the more conscious and purposive must adjustment become. Fitting for this adjustment belongs peculiarly to education. But here we fail. We have given too narrow an interpretation to education. Our narrow theory regards it as a preparation to adapt ourselves to a certain set of conditions, *i. e., those found existing*. The result is intellectual rigidity and obstinate resistance to evolution. The mental processes, moulded in certain mechanical forms of activity, find hardship in readjustment when conditions change, and, as we have seen, change is the rule to-day. Here, again, we are adhering too closely to the animal method, where movement is slow and rapid adaptation is not expected. Education should seek to develop a mental plasticity, a capacity for understanding and getting control of new situations and for making them.

To-day the great changes are social. Evolutionary conditions are pressing us toward a fundamental reconstruction of society. The reconstruction is a profound social variation. Education—that is to say, those who have the magnificent educational equipment of the nation in charge—should have foreseen this and made the new generation of youths ready for it, should have prepared them to recognize it as another great unfoldment of man, comprehending, assisting and developing it. But education has been engrossed in the comparatively petty rôle of teaching lessons. It has fitted children for immediate, *instinctive* environment, quite omitting rational, or higher social, environment. The result is present conditions—a practical deadlock of social forces. Education can not truly awaken the interest or command the confidence of the people until it assumes the higher function.

The present obstructors of social reconstruction or variation are the ill-educated though perhaps very much schooled. For schooling and education are not the same. The new social variation now beginning is an industrial readjustment which shall enable each individual, regardless of the accident of birth, to realize to their full value all of his native powers; and this will promote progress by removing artificial restrictions on individual variation. It would be very easy in this country, on the basis of accepted American principles, to effect the transition if educators, whose business is moulding minds to grasp the larger aspect of things and training them in the power to alter their views instead of reposing in fixed ones, had done their work. The current method is to impede social transitions; the intelligent course is to facilitate them. When educators rise above mere schoolmastering, social deadlocks and cataclysms will be of the past. The changes they involve will be welcomed.

While, therefore, the animal method of education is for static life—stability, with man it must be for dynamic life—change, improvement. And yet man's course in the past has not been complimentary to his intelligence, since many, if not most of his important alterations for the better have not been made by intelligent choice of the change itself, nor by choice of the best way; rather he has resisted as long as possible, until life became so bad that nature by some kind of punishment or eruption forced improvement upon him, as she does upon animals, by her power of destruction. This is the principle of revolutions. Sometimes they succeed in raising society to the level of the few higher individuals, but often they are suppressed by the forces in resistance to variation and adaptation.

This adaptation to a large nature brings with it a complete mental reorganization. Nor, indeed, is this lacking in physical confirmation. We can already trace certain corresponding physical changes in the constitution of the brain—the increase in association fibers in certain parts of the cortex shortly after eighteen years of age, indicated by Kaes's investigations, and the extension of Flechsig's association-centers in higher animals and particularly in man. Some of these cerebral changes seem to occur when increasing complexities of life are making new demands on intelligence.

Recent studies[18] suggesting that the human brain has not increased in average size for 20,000 years or more, also point to improvement in cerebral organization as the distinctive feature of the civilized brain. Further, both Kaes and Vulpius have shown that there are additions to the association fibers in parts of the brain long after thirty-eight years of age.

Every age brings its change of view. Acts that were once considered the most virtuous are to-day abominable. Why did not the people of past ages see at least some of these things as we do and know that they were wrong? What will future generations say of us in this respect? Are we never to reach a stage of culture that will enable us to think out these questions experimentally and intellectually, so that we may jump the trying experience of intervening ages? Are we never to eliminate dark ages? The processes of human progress are extremely crude. They are simply naturalistic. Now one of the ultimate functions of education, considered in the large, is to develop a science of progress. The naturalistic way is too expensive.

We are comparing the animals with their instinctive view of nature in its simplicity—an inherited mode of behavior developed on the basis of narrow experience—with man's mode of action. Man has developed his larger view of nature as complex through a more varied experience, but he acts to-day preponderantly on the instinctive method of the animals. While he has acquired the use of reason this has been only grafted on to the instinctive method of reaction. The cause of man's tardiness in abandoning the instinctive and adopting the intelligent method is that science is of modern and comparatively recent growth, and it is science that has entirely changed our conception of things by giving us a new view of life in revealing more of the inner nature of the universe. This has made the simple animal view inadequate. Wireless telegraphy by which England and America converse with one another through space, the X-ray with which we see through matter, and radio-activity which has established the complexity of the atom, indicate the incredible revolution that is going on in the character and scope of man's universe. But the animal takes the simple, immediate, and direct view of the world. It assumes and accepts without question that it sees the whole thing in its simple perceptions, and man has hardly at all emancipated himself from this method of interpreting.

We have found ability to profit by experiences the test of survival among all animals. With organisms low in the scale this learning is not an individual matter, but belongs to the species and takes the form of adaptation, and the advantage is bought at an enormous cost of life. A little higher, and individuals break away somewhat from inherited modes of behavior and action begins to be influenced by past

[18] *Amer. Jour. of Insanity*, Vol. 58, p. 1.

experience. Soon this becomes common, and the animal may then properly be said to learn, though there is no evidence that at this stage utilization of experience is ever conscious. When consciousness once becomes a factor in determining action, capacity to profit by experience is a measure of intelligence, and it is just this increased sensitiveness to experience that gives the facility in adjustment of which we have been speaking. Intelligence restricts the action of natural selection by enlarging the individual's range of adaptation and by giving insight into conditions and the power to create new ones. There is greater latitude for variation without destruction, and variation, again, may suggest other lines of progress by means of which nature's selection may be guided, so that she may find those fittest who are most appreciative of the larger, more universal environment which it is education's privilege to conceive and foster.

THE PROGRESS OF SCIENCE

THE NOBEL PRIZE IN PHYSICS FOR 1907

THE award of the Nobel prize and the Copley medal to Dr. A. A. Michelson, professor of physics in the University of Chicago, is of interest to Americans from more view points than one. Naturally and properly, it gratifies their national pride. But more than this, it marks a widespread recognition of the development of pure science which has recently occurred in this country, and the partial attainment of those ideals advocated so vigorously by Rowland in his "Plea for Pure Science," addressed to the American Association for the Advancement of Science at its Minneapolis meeting. In the past these ideals have been typified by the work of Franklin, Henry, Gibbs and Rowland—honorable names—but separated by intervals all too long.

But most important of all is the encouragement which pure science is now receiving from various sources. For while all prizes and research funds combined can do little to kindle or encourage the spirit of investigation in the mature mind, they do elevate the position of the investigator and foster the ideals of pure science in such a way as to make a career of research more attractive to able and ambitious youth. Great things may be hoped for American science when once the trend of young talent has set less exclusively to commerce and engineering.

In the history of optics Professor Michelson's work is certain to form a large chapter. His highly accurate determination of the speed of light is already a classic. His interferometer, devised for the purpose of detecting relative motion between earth and ether, bids fair to become the standard instrument for the measurement of all minute distances. Few facts in contemporary science are, indeed, more striking than the quiet and modest, but effective, manner in which Michelson and Benoit have, by their determination of the standard meter in terms of the red cadmium wave-length, morally, though not legally, established the wave-length of light as the international standard of length.

Another means for dealing with quantities in the sixth and seventh decimal places is Michelson's *echelon* grating which is perhaps the most powerful spectroscopic device now available. The product of his new engine for ruling diffraction gratings is awaited with great interest especially by astrophysicists.

The superficial observer may be tempted to identify the work of Michelson with the accurate determination of certain numerical constants. A greater mistake could not be made. For in nearly every case these determinations have been made possible by the discovery of some important method or principle whose fruitfulness it is impossible as yet to estimate.

For forty years after its enunciation the principle of Avogadro remained practically unrecognized by chemists. Nor is this tardiness in the recognition of scientific values confined to scientific men. Faraday had both the dynamo and the electric motor in full operation in 1831; but these machines were not placed on the market until about 1876. We therefore attempt no accurate estimate of the achievements of Professor Michelson, but merely extend to him the congratulations which he has so richly earned.

Professor A. A. Michelson,
Head of the Department of Physics in the University of Chicago.

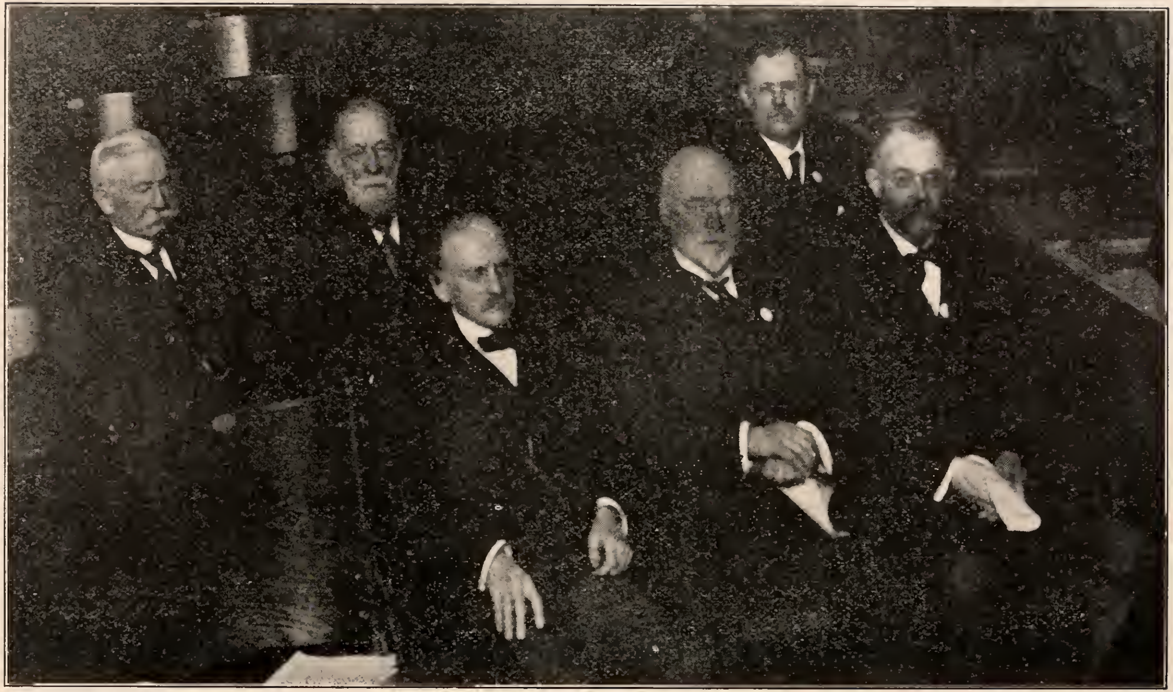
AMERICA'S CONTRIBUTIONS TO SCIENCE

The award of one Nobel prize in science to a citizen of the United States, even though his birthplace was in Germany, is a recognition as great as this country may properly claim. Indeed, it seems that the award in physics should have been made to Kelvin, if the plan of conferring the prize for distinguished services were to be followed, rather than the original instructions of Nobel's will, which required that the prizes should be conferred on those who contributed most materially to benefit mankind during the year immediately preceding. On the other hand, if the prizes had been conferred in accordance with the terms of the will, for "the most important discovery or invention in the domain of physics" "contributing to the benefit of mankind, the prize should have been awarded first of all to Dr. A. Graham Bell and Mr. Thomas A. Edison. The awards in the sciences so far made have been:

	Physics	Chemistry	Medicine
1901	Röntgen	Van't Hoff	Behring
1902	Lorentz and Zeeman	Fischer	Ross
1903	Becquerel and M. and Mme Curie	Arrhenius	Finsen
1904	Rayleigh	Ramsay	Pavlov
1905	Lenard	von Baeyer	Koch
1906	J. J. Thomson	Moissan	Ramon y Cajal & Golgi
1907	Michelson	Buchner	Laveran

The national distribution is: Germany 7, England 4, France 3, Holland 2, Denmark 1, Sweden 1, Russia 1, America 1, Italy ½, Spain ½. It is certainly somewhat disquieting if one accept these figures as measuring the scientific productivity of this country as compared with others, and there is, as a matter of fact, some reason to fear that one out of twenty does not seriously misrepresent our proportion of eminent scientific men. In his widely-quoted Harvard address, Mr. Owen Wister allows us three of his forty-three immortals. If he will kindly permit us to amend his list by making the obvious substitution in philosophy of Professor James for Professor Cohen, and the addition of Professor Newcomb and Dr. Hill, as astronomers without peers, we should be allowed one eighth of the world's most eminent scholars, which is probably a larger proportion than we possess.

That we have not produced great men in proportion to our population and our wealth amply justifies the arraignment which Professor Webster prints in the present number of the MONTHLY It must, however, be remembered that in so far as scientific productivity is measured by the number of men of international eminence a country may possess, this would refer to the preceding rather than to the present generation. Most eminent men have done their great work at least thirty years ago, and it is perhaps not discouraging that the possibilities for scientific work in this country were small in the seventies as compared with the opportunities to-day. Whether we are now accomplishing research proportionate in importance to the numbers engaged in it and to the facilities given them is a different question and one which it is probably impossible to answer. It appears from various bibliographies that about one seventh of the titles are American. There are no grounds for assuming that their average value is either above or below that of those from other countries. It seems that we are clearly out-classed by Germany in the number and value of our scientific publications, that we stand pretty close to Great Britain and France, and that we are surely before any other nation. Then if we wish to take the patriotic and optimistic point of view, we can find comfort in the fact that no other nation has in the past twenty years enjoyed such a notable increase in scientific activity. Should this activity continue to increase at the same rate for the next twenty years, there will be no occasion to shun comparison with other nations.



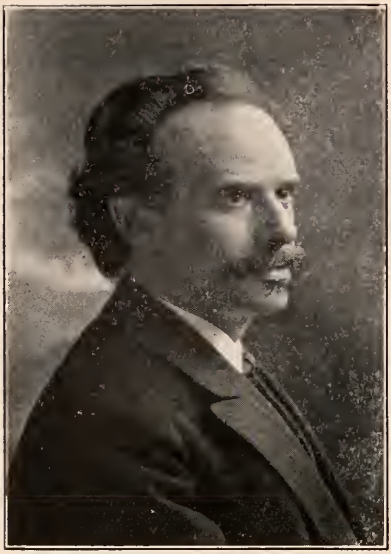
R. S. Woodward. C. M. Woodward. Edward W. Morley. John M. Coulter. Edward L. Nichols.

Professor Ludwig Hektoen,
Vice-president for the Section of Physiology and Experimental Medicine.

SCIENTIFIC MEN AT THE MEETINGS OF THE AMERICAN ASSOCIATION

It is one of the pleasures of attending a large meeting of scientific men to see the leaders of science and to personify work with which we are familiar by associating it with the face and presence of its authors. A lesser but still legitimate satisfaction is found in seeing their portraits, and we have regarded it as desirable to present to readers of the Monthly photographs of the officers of the American Association with whom they would like to be acquainted. In the last issue of the Monthly there was a portrait of the president, Professor Chamberlin, who, like Professor Michelson, gives distinction to the University of Chicago, and deserves a second Nobel prize, were there one established in geology. We give now a plate showing five presidents of the association and the chairman of the local committee. On the right is the president of the Chicago meeting, Professor E. L. Nichols, of Cornell University, eminent for his work in optics and electricity and honored for his services to education and scientific organization. Next is Dr. W. H. Welch, of the Johns Hopkins University, the retiring president, the leader among our pathologists both in research and medical instruction. Adjacent is Dr. E. W. Morley, who has recently retired from his chair at the Western Reserve University, equally distinguished as a physicist and as a chemist, the recipient of the Davy medal from the Royal Society at the same time that Dr. Michelson received the Copley medal. To the left is Dr. R. S. Woodward, the author of valuable researches in mathematical physics, as president of the Carnegie Institution occupying the most important executive scientific position in the world. By him is Dr. C. M. Woodward, of Washington University, known both as an engineer and as a leader in educational work, especially in the introduction of manual training. The remaining portrait is of Dr. John M. Coulter, head of the Department of Botany at Chicago and one of those who have given the university in the

Professor E. B. Wilson,
Vice-president of the Section of Zoology.



PROFESSOR FRANZ BOAS,
Vice-president of the Section for Anthropology.

PROFESSOR HENRY P. TALBOT,
Vice-president of the Section of Chemistry.

few years of its history a position in scientific research rivaled only by Harvard and Columbia.

The four vice-presidents of the association whose portraits are given are Dr. Ludwig Hektoen, professor of pathology in the University of Chicago and director of the Memorial Institute for Infectious Diseases, known for his work in pathological anatomy and bacteriology; Dr. E. B. Wilson, professor of zoology in Columbia University, eminent for his contributions to cytology and experimental morphology; Dr. Franz Boas, of Columbia University, whose researches have given him the leading place among anthropologists in the country, and Dr. Henry P. Talbot, one of those who has made the Massachusetts Institute of Technology a great center for chemical research as well as instruction. When the American Association can secure officers such as those mentioned here, we can with satisfaction place our working men of science beside those of any other nation.

SCIENTIFIC ITEMS

WE regret to record the death of Mr. Morris K. Jesup, president of the American Museum of Natural History. By his will $1,000,000 is given to the museum. Professor Henry F. Osborn, curator of vertebrate paleontology and professor in Columbia University, has been elected president of the institution to succeed Mr. Jesup.

THE hundredth anniversary of the birth of Charles Darwin, which occurred on February 12, 1909, and the fiftieth anniversary of the publication of the origin of species, which occurred on November 24, 1859, will be celebrated by the American Association for the Advancement of Science at its Baltimore meeting a year hence. Cambridge University also proposes an adequate celebration.

PROFESSOR REGINALD W. BROCK, professor of geology in the School of Mining, Kingston, has been appointed director of the Geological Survey of Canada.—M. Bailloud, of the Toulouse Observatory, has been appointed director of the Paris Observatory.—M. Henri Becquerel has been elected president of the Paris Academy of Sciences, and is succeeded in the vice-presidency by M. Bouchard.

THE
POPULAR SCIENCE
MONTHLY

APRIL, 1908

OUR INLAND WATERWAYS

By W J McGEE, LL.D.
U. S. INLAND WATERWAYS COMMISSIONER (SECRETARY OF THE COMMISSION)

WE are in the throes of our second waterway agitation. The movement extends from the Atlantic to the Pacific and from the Great Lakes to the Gulf, and involves every state and territory. The first agitation followed hard on the Revolution, and in far-reaching effect shared with the Declaration of Independence the distinction of opening the most important era in American history; the present agitation seems to promise a peaceful yet potent revolution in our material progress and in appreciation of the fundamental elements of national character and strength.

The Early Agitation and its Results

When the American colonies revolted against a tax imposed by a foreign monarchy the pendulum of feeling swung far toward purely local self-government throughout independent states. Yet within five years after the states were established and loosely confederated, questions of interstate relations arose; and when George Washington and others foresaw the increasing importance of commerce, and sought to develop the requisite facilities in connection with the typical interstate Potomac River, they induced Virginia and Maryland jointly to create a commission to devise plans of procedure. This was our original Inland Waterways Commission, the prototype, too, of the Interstate Commerce Commission; it represented the first recurrent swing of the pendulum toward interdependent organization. The commissioners met at Alexandria in March, 1785, and adjourned to Mount Vernon as Washington's guests. Obstacles arose, especially in the prevailing sentiment for supreme state autonomy; and with the view of increasing both the wisdom and the weight of their findings, they ended by arranging an interstate conference in Annapolis in 1786. Here opinion took shape as to the use of interstate and other waterways (then the sole lines of commercial movement) and as to the interdependence of the states; yet so many collateral questions arose, and so decided need was felt for larger authority, that no final action was taken beyond arranging for a joint convention of delegates from the several states to be held in Philadelphia in 1787. This convention, designed primarily to consider interstate commerce and waterways, took up also other relations between the states; the delegates found themselves confronted by the gravest possible questions affecting the prosperity and perpetuity of their respective communities and commonwealths; they deliberated and gradually adjusted these with intelligence and integrity unsurpassed in assemblages of men—and the outcome was the American Constitution, which made the infant commonwealths a nation.[1]

The work of the first waterways commission is significant in its bearing on later conditions and events—even to-day. In a sense the world was young in 1785; the sum of knowledge was but half, the knowledge of North America hardly a hundredth part, of that now prevailing—yet the original commissioners and first conferees and final delegates all took stock, so well as might be, of state and national possessions as affecting the conditions and prospects for the perpetuity of a growing country. To them and to the people who later adopted their findings land was the primary value, minerals a casual adjunct, forests an obstruction to travel and settlement yet a convenience, water an incident though a means of commerce, riparian rights an abstract albeit obstructive inheritance; and in the light of these views of fundamental values (the essential factors of national growth), certain powers were expressly granted by the people to the federal government, certain rights were expressly given or denied to the states, and any inchoate powers and rights were implicitly reserved for future division in accordance with the eternal principles recognized and set down—and without which were the constitution, in the words of Marshall, "a splendid bauble" (McCulloch *v.* Maryland *et al.;* Dillon's compilation, 1903, p. 277). Perhaps because it was what the great jurist afterward described as the "oppressed and degraded state of commerce" (Brown *v.* Maryland; *ibid.,* p. 539) that led to the creation of the commission and so to the conference and convention, the "commerce clause" of the constitution is notably condensed and comprehensive—so condensed that even within the lifetime of many of its framers the genius of Marshall was invoked to define it in opinions demonstrating that

[1] The chain of events is conveniently summarized by Woodrow Wilson, "History of the American People," Vol. III., p. 60, et seq.

the object of the instrument was to permit rather than to prevent exercise of governmental functions, so comprehensive that it has met and promises forever to meet a growth of commerce transcending the most roseate dreams possible in 1787.

The first-fruit of the constitution was renewed activity in commercial development: Washington's difficulties on the Potomac passed, and he planned an adjunct canal to connect the long-settled tide-water region with the virgin Ohio country beyond the mountains; Dewitt Clinton evolved his then stupendous project of uniting the Atlantic seaboard and Lake Erie by an artificial waterway; and just a century ago Albert Gallatin, sustained by the sympathy of Thomas Jefferson, outlined a plan for waterway improvement and commercial development which in broad adjustment of the means and ends of national development has never been surpassed and seldom approached.

With the conquest of natural power through the control of steam (which indeed led to one of Marshall's masterly interpretations of the "commerce clause") conditions changed, and the railway opened an era in settlement and production such as the world never before saw and may not see again—indeed, while material and immaterial agencies can not well be compared, it is not too much to say that just as the American constitution made our nation, so the American railway made our country a world-power. Population and riches beyond the imaginings of the nation's founders followed and were bound by the iron bands until great commonwealths bridged the continent, until it were easier to think of millions than of thousands before, until one seventh of our swollen wealth came to be railway property and its ownership a factor in law-making, until every-day ideas of domestic travel and transportation came to connote railways alone.

Meantime the prophetic visions of Washington and Jefferson and Clinton and Gallatin faded—for a time. True, the canals projected by the earlier commissioners along the Potomac and connecting Delaware and Chesapeake Bays were constructed, Erie Canal was completed, the Delaware and Raritan, Morris, Lehigh and a dozen others were put into operation—yet they gradually passed into the ownership or controlling influence of railway corporations, and half of them were virtually abandoned. True, the steam packet traffic of the Mississippi and Ohio attained high efficiency and a sumptuousness of appointment starting back-woods simplicity toward culture, while the Missouri was so navigated as to open the opulent storehouses of the vast northwest—yet, as railway enterprise grew and the slip-shod ways of slave-labor passed, the territory was tapped and the traffic transferred to overland lines until river traffic was virtually dead, the water-fronts of every river town from St. Paul to New Orleans (save "Natchez on the Hill") controlled by railway interests, and the once resplendent river vessels reduced to rattletraps. True, federal provision for river improvement continued sporadically under what was long jocosely styled the "pork barrel" committee, from which the stigma finally faded under the leadership of the stainless and brilliant Burton, until the aggregate expenditures for rivers and canals reached several hundred millions—yet the federal policy remained repressive and commonwealths and capitalists held aloof: there was never a cabinet officer charged with the duty of developing or maintaining commerce by water, the admirable engineer corps was barred from initiative by custom and even by law, the Rivers and Harbors Committee found its chief function in scaling down or turning down estimates and projects presented by the people. Mechanism for progress there was none; of means of repression there were many. And population and production gradually overtook and then outpassed railway capacity.

The Re-awakening

Shortly after the abundant harvests of 1906 were gathered a great popular movement began to stir the interior and the west, and a cry went up against an intangible but real tyranny of transportation that barred produce from markets and withheld supplies from the producers. The movement did not arise in a day; by some it was foreseen for months, by others it was felt only when the pinch of winter came with fuel-famine and need for clothing and transported food-stuffs; yet even by mid-autumn some millions of citizens were astir—far more than felt the thrall of foreign stress a century and a third before. At first the movement was vague and without definite aim; groups met for discussion, conferences were called, complaints were voiced, and then county boards and state legislatures were invoked, and national lawmakers were deluged with appeals from half a million constituents. The situation was simple—within a decade the productions of the northern interior had doubled, while transportation facilities had increased but a small fraction. Fortunately it was sized first by railway men: there were not cars enough; neither were there locomotives enough to move the cars required for the products, nor tracks enough to carry the trains; there were not terminals enough for the rolling stock, nor could these be acquired without imposing a ruinous burden; there was not iron enough in the country to build the cars and locomotives and tracks, not available labor enough to mine and smelt the ore—and besides the cost (estimated, *e. g.*, by James J. Hill at $5,000,000,000 to $8,000,000,000, or one third to one half of our aggregate railway investments) would consume so large a part of our currency as to paralyze other business. Even if the extension were possible, the relief would be but temporary; with normal growth of the country and ordinary increase in production it would be effective for only seven to ten years. So railway magnates and the masses began to see alike that the congestion of freight was a general condition affecting every industry and the entire country, and one not to be remedied by local and temporary means. Thenceforward discussions and conventions took a definite aim—and for the first time in our industrial history, railway corporations, commercial organizations, producers, and consumers, all united in a common movement for the common good.

Seen large, our primary industries are production and distribution, the latter effected by trade and transportation; and in 1906 it became clear that production had so far outgrown transportation and trade (including every phase of merchandising and banking and broking) as to prevent the normal development of either—*i. e.*, entire sections of the country were confronted by the stern necessity of finding new and more economical transportation facilities, or else ceasing to develop. In fact while citizens and statesmen were seeking facilities and discussing the resumption of water traffic, settlement and production actually stopped over scores of thousands of square miles in the Dakotas, Montana, Wyoming, Washington, Oregon and California: nor can it recommence, save perhaps feebly and sporadically, until transportation is provided. For conditions are changing: In the first place, human nature being as it is, the luxuries of yesterday are the necessities of to-day, so that the time of the independent and self-supporting squatter family has passed, and that of the interdependent settlement or community united on the joint basis of human sympathy and convenient currency has come in its stead. In the second place, water and fuel are no longer mere redundancies if not obstructions to settlement, but essentials to be gained only through collective action. In the third place, the multiplication of communities necessarily involves a much more rapid increase of lines of communication, in accordance with the mathematical law of combination: two communities may be connected by one line, while three communities require three lines; four demand six lines, five need 10 lines, six, 15 lines, eight, 28 lines, twelve, 66 lines; if the lines were not combined, the county seats of a state of a hundred counties would require 4,950 lines of communication to connect them, while the thousand towns of a section would require 49,950 lines—so that a reason for the breaking down of transportation systems in a growing country is the inexorable physical law under which the lines connecting communities increase in rapid ratio. Thus the congestion of traffic in the land of magnificent distances forming the interior and the west in 1906 was inevitable; production and trade had simply outgrown transportation facilities; the railways failed because the marts were too far apart for their carrying capacity—and the old-time packets were gone!

Creation of the Waterways Commission

Of the conventions of 1906, two were especially effective; that of November in St. Louis, out of which grew the Lakes-to-Gulf Deep Waterway Association, and the Washington session of the Rivers and Harbors Congress in December, at which the attendance and interest were beyond precedent. During the latter, strong delegations called on the president, the speaker of the house, the chairman of the Rivers and Harbors Committee; and later the Lakes-to-Gulf Deep Waterway Association led in petitions to the president from organizations of citizens in the interior to "appoint and empower a commission or board of five persons to prepare and report a comprehensive plan for the improvement and control of the Mississippi River system and other inland waterways in such manner that the rivers of the country may be fully utilized for navigation and other industrial purposes." Meantime the Rivers and Harbors Committee reported a bill providing for a somewhat similar commission, though in the pressure attending the closing days of a short session it failed of final action. A score of petitions reached the president during the first week of March, 1907; and on March 14, after combining the two movements toward the same end, he created the present Inland Waterways Commission of nine members, through an instrument of signal vigor and originality:

> In creating this Commission I am influenced by broad considerations of national policy. . . . Our inland waterways as a whole have thus far received scant attention. It is becoming clear that our streams should be considered and conserved as great natural resources. . . . The time has come for merging local projects and uses of the inland waters in a comprehensive plan designed for the benefit of the entire country. . . . The task is a great one, yet it is certainly not too great for us to approach. The results which it seems to promise are even greater. . . . The present congestion affects chiefly the people of the Mississippi Valley, and they demand relief. When the congestion of which they complain is relieved, the whole country will share the good results. . . . It is not possible to frame so large a plan . . . for the control of our rivers without taking account of the orderly development of other natural resources. . . . The cost will necessarily be large, . . . but it will be small in comparison with the $17,000,000,000 of capital now invested in steam railways, . . . [which] investment has been a constant source of profit to the people, and without it our industrial progress would have been impossible.

These fundamental utterances, with requisite explication of details, outlined a policy to which people and press responded with enthusiasm.

The commission began active work on the Mississippi in May, followed by inspection trips through the Great Lakes and down the Mississippi and lower Missouri in September and October. They were accompanied by the president from Keokuk to Memphis in what was designed as a simple inspection yet proved to be at once the most notable pageant in the history of the Mississippi Valley and the most impressive demonstration any president ever saw—for in addition to the fact of his presidency, Theodore Roosevelt was as a Moses leading the people from an "oppressed and degraded state of commerce" in which they found themselves beleaguered, as did their forebears a century and a quarter before. Nearly all the water craft of the river system were assembled; railways abandoned schedules and stopped freight traffic to accommodate specials; entire towns were evacuated that the inhabitants might gather on the river front. On the average each river town—Keokuk, Quincy, Hannibal, Louisiana, St. Louis, Cape Girardeau, Ste. Genevieve, Cairo, Memphis, and the rest—showed more spectators standing out to salute the presidential party than its entire population; while day and night the air was rent with acclamations of voice, steam whistle, shrieking siren, salvo of guns, and roar and rattle of fireworks.

Individual members of the commission, singly or in groups, studied the Ohio, the upper Missouri and its tributaries, the vast Columbia Valley and Puget Sound, the California rivers, Rio Colorado, the streams of the Gulf slope, and the waters and projects of the Atlantic slope. And the interest of citizens grew in every state, until the autumn of 1907 produced such a crop of conventions and such a volume of support for waterway improvement as no other peaceful issue ever evoked. The Irrigation Congress in Sacramento in September; the Lakes-to-Gulf meeting at Memphis, the Upper Mississippi Improvement convention at Moline, the Interstate Waterway convention at Victoria (Texas), and the celebration of the opening of Hennepin Canal at Sterling, in October; the Trans-Mississippi Congress at Muskogee, the Atlantic Deeper Waterway conference at Philadelphia, the Drainage Congress at Baltimore, the Gulf State Waterway convention at Birmingham, and the Ohio Improvement Association meeting at Wheeling, in November; the National Rivers and Harbors Congress at Washington in December—these were among the national or interstate conventions devoted either primarily or secondarily to waterway improvement and attended by hundreds or thousands of delegates from every state and territory and representing every industrial and public interest of the country during the closing months of 1907. And state executives have commenced to combine not only with their constituents but with each other; at Sacramento there were five governors, at Memphis eighteen, at Muskogee and Washington half a dozen each and at several others from one to three.

Nor is this the end: Under their broad instructions the commission found it needful to consider not merely the improvement of our rivers but the use and conservation of related resources; and deeming the proper administration of these a duty devolving jointly on the nation and the states, they asked the president to follow Washington's example by invoking the advice of our several co-sovereignties in a conference on the conservation of natural resources. Acceding to the request, the president has invited all the governors of states and territories (each with three advisers) to convene in the White House in May next and discuss ways and means of conserving the waters and other resources of the country with him and with those cabinet officers, justices of the supreme court, senators, and representatives whose duties may permit attendance—and nearly all the executives have already accepted and named their coadjutors.

So the events of the young century strikingly duplicate those immediately succeeding American Independence: Again questions of commerce and interstate relations have become paramount—and in multiplied magnitude and complexity; again it has become necessary to take stock of those material possessions on which the perpetuity of our people must depend—though now the possessions comprise not only the land areas contemplated by the founders but the still greater values residing in waters and woods and mines and soils, which were inchoate then but have come into actuality and dominance through the natural growth and orderly development of the nation; again it seems necessary for a waterways commission to appeal from its own court to an interstate conference representing that highest tribune, the poeple—though now the appeal can not result in a federal constitution (which came from the former in such perfection as to meet all later needs), yet can hardly fail to bring about a closer readjustment of the magnified sovereignties and multiplied possessions developed on that fundamental platform. The president has expressed the feeling that the May conference promises to be one of the most important assemblages in our history; and the people and the press have concurred with a unanimity seldom evoked, and giving assurance that the anticipation will be realized.

Nor is it to be forgotten that in advocating the development of our natural channels of commerce, Roosevelt is but following the footsteps of Washington and Jefferson, and Root but treading the path blazed by his early predecessor Gallatin; though they are supported in cabinet, notably by the progressive Secretaries Garfield and Wilson, far more vigorously than were the pioneers—indeed, never before have a people and an administration been so firmly united in efforts to improve an "oppressed and degraded state of commerce" with the attendant conditions of national prosperity.

The Need for Navigation

The most pressing demand of the day connected with our inland waterways is for navigation and carriage of freight. The need is urgent. The notably reserved and cautious Interstate Commerce Commission has just declared:

It may conservatively be stated that the inadequacy of transportation facilities is little less than alarming; that its continuation may place an arbitrary limit on the future productivity of the land; and that the solution of the difficult financial and physical problems involved is worthy the most earnest thought and effort of all who believe in the full development of our country and the largest opportunity for its people.

While we now have 26,200 miles of navigable rivers and some 2,800 miles of canals in operation (with nearly as much more inoperative or abandoned) which during 1904 carried, respectively, 127,000,000 and 5,000,000 tons of freight, we have also 222,500 miles of railways which during 1906 carried 1,631,374,219 tons—*i. e.,* although the United States has a more extensive and better distributed natural system of inland waterways than any other country, and despite the fact that water carriage costs on the average but a third or a fourth as much as rail carriage, less than one ninth of our freight lines are waterways, and only one twelfth of our commodities are carried by water. And of our aggregate assets of say $107,000,000,000, our steam railways have risen to some $16,000,000,000 or $18,000,000,000, or nearly one sixth, which even at first sight seems out of proportion; and the disproportion becomes still more glaring when current production is compared with railway earnings—the former in 1906 reaching $7,000,000,000 to $10,000,000,000 (according to mode of estimate of farm products) and the latter $2,325,765,167, or fully one fourth as much. The case is clear; we are employing extravagant agencies and paying exorbitant rates for transportation; the prices of our staples depend too little on cost of production, too largely on cost of carriage.

The condition is not new, only grown worse yearly; it led largely to the establishment of the Department of Commerce and Labor, and wholly to the creation of some of its bureaus; it has led to legislation in several states, and thence to conflict between state and federal authority in a number of cases; and above all else it has led to such paralysis of settlement and production as to check the growth of the country. In a dozen states the "oppressed and degraded state of commerce" is not an idle phrase; it denotes a condition now intolerable, and soon to be suicidal unless relieved, and that by measures both prompt and permanent. Our productions are ample and our ports sufficient to maintain a beneficial balance of international trade; yet products and ports were but a burden unless the one can be laid down at the other at prices permitting interchange with the rest of the world. Our Panama Canal is a gateway to the nations—yet of what profit to us unless our exports can be delivered on the sea-board at a competitive figure, *i. e.,* at a reasonable increase on the cost of production? The time has come to inquire whether Boston, New York, Philadelphia, Baltimore, New Orleans, San Francisco, Portland and Seattle are to be gateways for growth or mere leak-holes of national wealth; whether the advantages of great-circle steam-lines may not overbalance productivity and transfer dominant commercial lines and centers beyond our boundaries; whether we are able to balance our magnificent distances and splendid productivity in such wise as to maintain that economy of transportation and reasonableness of delivery of both imports and exports requisite for a world-power! The questions are nation-wide. Twenty-odd states and forty million inhabitants of the interior are actually suffering from the congestion; fifteen states and thirty million people on the Atlantic coast are complaining under imposts of burdensome traffic; the western states with their seven millions, which would triple in ten years were the burden removed, find their growth paralyzed by the same cause.

Will the improvement of waterways and the restoration of water traffic bring relief? Certainly the plan promises much, while no other promises anything. It has been estimated that our 29,000 miles of inland waterways (exclusive of lakes, bays, sounds, etc.) might be doubled at a cost of $500,000,000 to $800,000,000,[2] *i. e.*, one tenth of the amount required to raise railways to the capacity required to-day; and it is safe to say that when the nation adopts a progressive waterway policy, private enterprise will build the boats—and that when this is done our great productive areas can deliver exports at and receive imports from the coast cities at an average of not more than half and probably less than a third of the present cost. With the readjustment of transportation lines, the railways might change from trans-continental carriers of bulk freight to feeders of the waterways; yet their efficiency as public utilities need not decline, and their profits might increase, as recently held by President Harahan (of the Illinois Central Railway). The superior economy of water transportation, which has been shown statistically over and over again, may be illustrated by the fact that a river packet can be built at a cost of two miles of railway (including rolling stock but not right-of-way or terminals) and will carry three 400-ton train-loads of freight; or that a tow and barges suited to the Mississippi-Ohio traffic can be built for the cost of four or five miles of railway and will carry 150 train-loads; or that the entire cost of waterway development contemplated would hardly suffice to build and equip a single trans-continental double-track railway with the requisite rights-of-way and terminals.

Nor is waterway improvement a new venture, involving unknown

[2] The Bartholdt bill now before the house of representatives provides for a bond issue of $500,000,000 for waterway improvement; the Newlands bill pending in the senate provides for a waterway fund of $50,000,000 to be continued by appropriations or bond issues as needed.

factors: Many of the problems were solved practically by Washington and Clinton and their contemporaries through canal systems that would unquestionably be in use to-day had not the railways better met temporary needs; most of the rest have been solved in European countries that are to-day better advanced than ourselves both in waterway development and in that adjustment of transportation to production on which national prosperity must depend. In the light of this experience it would seem easy to return to and perfect Gallatin's great waterway system; and in the light of present needs, it should begin in the interior with a deep channel from the Great Lakes to the Gulf, and in the East with an Inner Passage from Massachusetts to Florida—and these main arteries should be coupled with passages skirting the Gulf coast and with improved tributaries in such manner that standardized barges may pass from Benton to Boston or to Brownsville, or from any lake port to any sea port with some choice of routes: and eventually through the Minnesota and Red River of the North to Lake Winnepeg and Hudson Bay, in order that the grain-fields of the Canadian plains may find outlet to the sea during a longer open season than that of Hudson Strait. And at the same time the pressing need of the Pacific Coast should be met; the treasure-houses of the Columbia and Snake should be unlocked and a way made into Puget Sound, while the golden gardens of California Valley should be opened to ships going down to the sea in order that the grains and fruits now rotting in bin and on branch may be turned to human good and national welfare. The details are innumerable; the demands irresistible.

Among the waterways, three or four should be improved not merely to meet commercial needs, but as a patriotic duty: First in importance is the Lakes-to-Gulf project; for should disaster befall and Canada pass into unfriendly hands, the enemy might within a week put war vessels into the Lakes through Welland Canal or the still larger Huron Canal (of which we hear little thus far), in which case catastrophe could be averted only by a waterway of war-ship capacity from the Gulf to Lake Michigan. Scarcely less important is the protected passage projected for the Atlantic slope, though since the baseless Cervera scare the details need not be pursued; while the connection of the Columbia with Puget Sound, and the extension of San Francisco and Suisun bays need no more than mention in connection with the military possibilities of the day and the "national defense" of the founders.

The Value of Water in Itself

While navigation is the most pressing use for our waterways, there are others of no less present value and future promise. Neither Washington's waterway commissioners nor their successors took much account of water save as a way for commerce; they failed to recognize water in itself as a resource and hence an object of property, except vaguely under the imported common-law notion of riparian rights—*i. e.,* rights vesting essentially in the land with the water as an appurtenance thereto. Now as settlement extended into the arid regions, the pioneers learned through the bitterest experiences within human capacity that water itself is a primary value, indeed the greatest of all values; and gradually a new concept arose, under which individuals, then communities, and finally (in some cases) states came to recognize actual ownership in water.[3] As the concept took form it became clear that the value of land itself—the chief value reckoned by the founders—is determined chiefly by the water on or in its substance, for if too wet it is worthless, if too dry a menace to life; indeed the market value of each acre of arable land in the United States to-day is determined within some ten per cent. by the associated water—*i. e.,* the water-value is nine when the land-value is one.

The new concept of water as a primary value in its substance or corpus is not yet crystallized in statute or even in custom; it has come up with the natural growth and orderly development of the country; and it is still an open question whether the powers of the states or of the nation are paramount—though the view that the value pertains to the people and is to be administered primarily by the nation on account of its interstate quality, and secondarily by the states as an appurtenance of the land, would seem to accord with the principles framed into the constitution and interpreted by Marshall and contemporary jurists. Certainly a value of such magnitude as the 40,000,000,000 cubic feet of water flowing annually down to the sea is a natural resource too closely connected with the peace and perpetuity of the nation to long remain neglected; it alone would warrant conference between the executives of state and nation. It is within the memory of many now living that a man able to estimate the value of a raft of logs or a patch of standing timber more closely than his fellows, taking advantage of the fact that forests were still regarded as little more than obstructions to settlement, began to buy small tracts nominally as land but actually for the timber, and continued turning over his growing capital and buying larger and larger tracts as the pineries were despoiled, until he became an undercurrent of power in legislative halls and at last gained wealth probably exceeding that of any other individual in the world's history; and he but exercised prevision in taking freely that which was not at the time regarded as a

[3] Summarized by Hess in "An Illustration of Legal Development—the Passing of the Doctrine of Riparian Rights" (*Am. Polit. Science Review*, Vol. II., November, 1907, pp. 15–31).

value. Now, the vast inherent value of our forests is but a bagatelle in comparison with the inherent value of our living waters; the time is ripe for taking stock of this immeasurable resource; and it behooves the people through the representatives in whom they repose confidence to claim this greater heritage on which the lives of the generations must depend.

The Utilization of Power

An ill-recognized value of running water resides in its power, a quantity doubtless sufficient to drive mills and trains and boats, and furnish light and heat and domestic motors for a century or two after our coal is gone. Hitherto this resource has been neglected, partly because the concept of inherent or potential value remained inchoate, and power was not felt to exist until actually developed by dams and races and penstocks; yet the realization that 40,000,000,000,000 cubic feet of river water descending an average of 2,500 feet is a rich possession can not long be delayed, for it exceeds 300,000,000 horse-power, or thrice the pulling power of all the horses now living in the world—even if the sum be tithed for safety it will still reach 30,000,000 horse-power, which at $20 per year would be worth $600,000,000 annually (or more each year than the estimated cost of improving all the rivers of the country), equal—at 3 per cent.—to a capital of $20,000,000,000. And the availability of water-power entered on a new era with the perfecting of electrical transmission in the last decade!

Though the time is not ripe for discussing utilization, a case may be instanced: The boldest water-supply project in our history was undertaken when Los Angeles, a city of only 150,000, bonded itself for $23,000,000 to purchase a riverlet 250 miles away; it seemed an appalling price for continued civic life, yet the people were ready to pay; and it was not until the plans for piping were nearly done that the incidental value of the power was realized—and negotiated at rates yielding ten per cent. on the bonds! Suffice it to add that even if the improvement of our waterways for navigation were to cost five or ten times the amount estimated, the water-power developed incidentally in connection with the works, if judiciously administered, would alone pay the entire cost in from five to twenty years. Picturesque streams and cataracts should be saved as scenic features, for natural beauty is a national asset beyond material measure; but the ignoble wild should be harnessed to the plow of progress.

Fortunately, while the founders failed to define the proprietary interests in the running waters, they recognized their interstate character and granted the nation certain authority over them; and this has been repeatedly confirmed by the courts and crystallized by statutes authorizing the retention of rights in power developed by private means, the time limitation in grants for state or private works, and the leasing of power developed on public works.

Land Waste and Reclamation

Each year the rivers of mainland United States pour into the seas a thousand million tons of richest soil-matter in the form of suspended sediment—an impost greater than all our land-taxes combined, and a commensurate injury to commerce in the lower rivers which are rendered capricious and difficult of control by the unstable load. Moreover, the greater part of the sediment is swept down during floods which annually destroy and depreciate property to the average value of scores if not hundreds of millions, besides preventing development of the fertile lowlands; and furthermore, expert determinations show that the organic contamination of running water varies directly with the suspended sediment, so that muddy water is a common cause of disease and death. Now any comprehensive plan for waterway improvement will necessarily involve prevention of floods by means of far-sighted forestry, intensive farming, judicious reservoir-construction, and other devices whereby the waters will be compelled to flow even clearer and purer than they did before nature's delicate balance between rainfall and slope and natural cover was disturbed by settlement and industry. It is conservatively estimated that the benefits resulting from the clarification and purification of the water will in themselves balance the entire cost of the system of waterway improvement required to relieve the existing congestion of traffic.

And the control of the waters involves reclamation of arid lands by irrigation, and of certain swamp and overflow lands by drainage. It is estimated that these means, extended to projects already in sight, will fit 150,000,000 acres of highly fertile land for settlement, thereby furnishing (in forty-acre farms with necessary villages) homes for an additional population of 20,000,000—or four times that number under the intensive culture which finds "ten acres enough." The expense involved might by judicious administration be made incidental to that required for improving the waterways for navigation (which would hardly exceed that of a trans-continental railway line), while the direct benefits, as illustrated by the operations of the U. S. Reclamation Service to date, would amount to many times the cost.

Development and Conservation

Such are some of the conditions and values brought into view by the recurrent congestion in transportation—for which relief is imperative, else the nation must sacrifice its supremacy and by reason of its own bigness yield the van of progress to lesser contemporaries. The cost of relief will be large, as the nation is broad and its productions opulent; yet from the standpoint of traffic alone the game will be worth far more than the candle. In addition, the prevention of soil-wash and the purification and clarification of the streams will, as the value of water increases with multiplied population by natural growth and orderly development, more than balance the entire cost; if the works be planned to utilize the incidental water-power, it alone will (with a moderate working capital) not only pay the entire current cost but replace our rapidly decreasing mineral fuels as a source of energy; and a dozen incidental advantages and values clamor to be entered on the credit side of the ledger. Eventually, if not to-day, the nation must take stock not merely of its land but of the 150,000,000,000,000 or 200,000,000,000,000 cubic feet of water annually falling from the heavens on the 2,000,000,000 acres of that land and giving it value—must conserve and control the boon in such manner as to minimize destruction and loss and maximize benefits for citizens and country: and any present step should take the right direction. Other resources, too, demand conservation—especially the timber and coal and oil and iron supplies already largely gone. The sole obstacle to-day is precisely that which confronted Washington and his contemporaries in the earlier waterway agitation—the doubt as to who should act in the public interest. The obstacle was overcome one hundred and twenty years ago: Can its present phase then deter the nation made great by the infant effort? That is the question to be weighed by the executives of states and nation in joint conference in the White House next May.

Fortunately the later statesmen hold a point of vantage; for America has become a nation of science. The sum of knowledge has gained a hundred per cent. and knowledge of the country and its resources has grown a hundred fold since 1787. The lands have been explored and surveyed; the mines have been opened and tested; the rainfall and rivers have been measured; several of the sciences have taken form and placed facts and principles at command; and under the stimulus of a far-sighted patent law invention has harnessed natural forces in a manner inconceivable even a century ago. The early ideas were of extension and diffusion; the present needs are for intensive development and conservation. And while the later stress may be less than the earlier it is attended by wider experience and surer modes of thinking, so that action ought to be easier and safer. Certainly the stress will increase until relieved; and there are those who feel that the present issues and the prospective conference may well mark another epoch in national policy and national growth.

ACCIDENTAL RESEMBLANCES AMONG ANIMALS. A CHAPTER IN UN-NATURAL HISTORY

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THE naturalist of to-day is perhaps unduly saturated with the belief that animals and plants adapt themselves to their surroundings. He has seen so many and such admirable examples of this, and in every field of his work, that he is apt to conclude that the principle of adaptation can be called upon to explain phenomena which when critically considered may prove to be not adaptive at all. In the familiar case of an insect whose colors suggest lichen-covered bark, or a dead leaf, or a flower, we have come to conclude, since we have seen many examples of demonstrated utility, that the resemblance is significant, that it protects the insect against its enemies and that it has been the outcome of a series of evolutional changes which have made the protective coloration more and more complete. We have even reached a point, some of us at least, where we neglect to scrutinize the evidence that the creature in question frequented the kind of bark, leaf or flower which it resembles, or that, if it did, it was thereby protected so completely as to ensure its survival. We have reached the point, to make this attitude clear, when we hold up before our students a butterfly mounted on a twig and point out the marvelous "protective" resemblance between the butterfly and the neighboring pressed leaves, without suspecting that the leaves belonged to a beech tree "made in Germany," and that the butterfly came from the East Indies!

So also is our attitude a lax one in the case of animals which resemble other animals and are thereby protected, like moths which resemble wasps, flies which can be mistaken for bees, butterflies which are similar to butterflies known to be rejected by birds, etc. For we have seen so many instances of undoubted mimicry that we are apt to accept resemblances as of this type, even if they have not been experimentally demonstrated. That such accurate resemblances, on the other hand, could occur even in animals which live side by side *and yet mean nothing,* would be something of a heresy to many evolutionists. Yet I am inclined to believe that this is a fact—although to prove this in concrete instances would be at the moment difficult. However, it can, I think, be established indirectly and by striking analogies. For if there occur among animals numerous resemblances which mean nothing, we may justly be skeptical of other resemblances—unless their value can be experimentally proven.

In point of fact, if we sift out the cases in which mimicry and protective coloration have been demonstrated beyond question, we find that their number is by no means as large as we at first assume. And of the remaining cases, probable, or imperfectly proven, we should, in fairness, leave open the possibility that what seems protectively colored or mimetic resemblance might in the end turn out to be accidental and meaningless. And in the present notice it may be interesting to refer to these meaningless resemblances in order to show both that they are abundant, and that they are excessively complicated—in certain cases, even more complicated than those which are commonly regarded as typical, if not brilliant instances of protective or mimetic adaptation.

FIG. 1. CARAPACE OF A JAPANESE CRAB, *Dorippe* picturing in relief an oriental face.

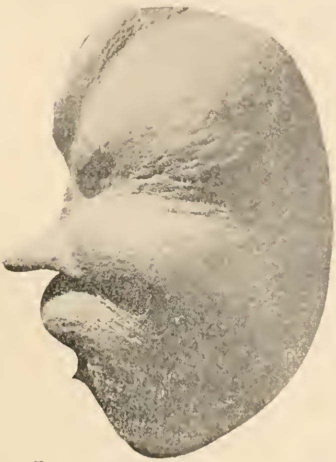

FIG. 2. WHALE'S "EAR-BONE" which in profile suggests the face of a Scandinavian fisherman.

As an example of a meaningless resemblance let us first refer to the Taira-crab, a *Dorippe,* Fig. 1, on whose back a human face appears strikingly portrayed. This crab occurs rather abundantly in a region of the Japanese coast where many centuries ago a great naval battle took place: and *it was only after this time,* local Buddhistic tradition states, *that a face of a Taira warrior appeared on each carapace,* as tangible evidence that the souls of the dead migrated into the bodies of these lower animals![1] Now, the resemblance in this case is developed to an almost uncanny degree; the face, first of all, is clearly oriental—even more Chinese or Corean in type than modern Japanese, but from this very fact the more singular, since at that time but few

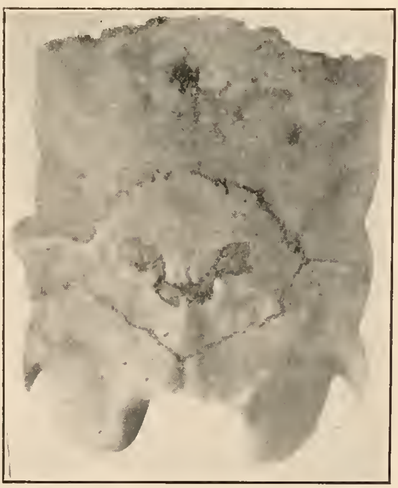

FIG. 3. OCCIPUT OF GOAT'S SKULL, showing face of Hanuman monkey.

[1] A.D. 1184, at Dan-no-ura, the Taira clan was exterminated by the rival Minamoto headed by Prince Yoshitsuné.

Ainos had been absorbed into the Japanese race, and its physical features were therefore, on historical evidence, more strongly continental. The face, in the second place, is that of a drowned man: it is horridly infiltrated, the nose swollen and the mouth widely opened. In such a case the complicated nature of the meaningless resemblance can hardly be overestimated. For we have in it, as will be seen, a series of resemblances which are added one to the other, from the general to the specific, in somewhat the following way: human face (in itself, of course, a very complicated structure): male: young: oriental: primitive Japanese: drowned.

A second meaningless resemblance is shown, Fig. 2, in a whale's "earbone" which was found on a beach in Norway: it portrays in half relief a Scandinavian face of low caste, and with almost absurd accuracy—with rounded cheek-bones, flattened nose-bridge, small upper lip and receding jaw.

In both of these cases there is an extraordinary meaningless correspondence between the resembling objects and the especial locality in which they occur. And this condition occurs with amusing frequency.

A case in point occurs in the skull of a goat, Fig. 3, picked up in Agra, which shows on its supra-occiput the face of the common monkey of the locality, the Hanuman (*Presbytes entellus*), for it shows (with a slight tax on the imagination) the front view of this monkey's forwardly directed beard, cheek-tufts and brow-hair, and these, too, in light tone against the dark-colored face.

Another possible case is that of the squash seeds, Fig. 4, which in drying acquire irregular depressions on their surface, and thus produce

Fig .4. Squash Seeds picturing Ideographs.

the effect of idiographs. They are said to have come originally from Japan, but in any event so perfect are the "characters" that I have known a Japanese scholar to puzzle over them for several minutes in his effort to read them!

A somewhat analogous instance, Japanese (noted by my friend, Dr. Yatsu), is that of the "Tokugawa fish," a small species of *Salanx*, which is said to have appeared in Yedo (Tokyo) shortly after the last dynasty of regents made their seat there. This fish is curious in that its head bears the badge of the Tokugawa family, the three *Asarum* leaves conjoined. This effect is produced by the lobes of the brain, which can be clearly seen through the transparent headroof.

An example which pictures a human face almost as strikingly as in the Taira crab is seen in the chrysalis of the butterfly, *Feniseca tarquinius,* Fig. 5.[2] For here the resemblance is developed in remarkable

FIG. 5. PUPA OF THE BUTTERFLY, *Feniseca tarquineus.* (Cut loaned from *Entomological News*, through the kindness of its editor, Dr. Skinner.)

detail, with forehead wrinkles, eyebrows and lids, aquiline nose, thin determined lips and straight mouth—all in this case as palpably Caucasian as the Taira face was proto-Japanese. If the present photograph had been taken from a larial mask of Tarquin himself, it could hardly appear more human!

A second pupa-portrait is given in Fig. 6, in the case of *Spalgis S-signata* Hol. In this instance not only are the characters of Feniseca paralleled, but there appear hair (frankly not a vast chevalure) on the "head," pupil in the "eyes," and the general appearance in grotesque of the head of a chimpanzee. Not remarkable, therefore, that the habitat of the "mimicking" insect is West Africa!

A third pupa portrait, Fig. 7, again a Feniseca,[3] but I do not know

[2] For the permission to use this figure, and the loan of the cut itself, we are greatly indebted to Dr. Skinner, the editor of the *Entomological News.*

[3] For this I am indebted to Professor Wheeler.

FIG. 6. PUPA OF *Spalgis*, showing "monkey face." (From figure published, 1892, in *Psyche*.)

of what species, is taken from a photograph of a dried specimen. It has the face-like appearance, and suggests amusingly the restoration of the *Brontosaurus*, in the American Museum.

Still another meaningless resemblance is in the death's head moth, *Acherontia atropos*, which shows a "remarkably faithful delineation of a skull and bones upon the back of the thorax." And in allied species the skull is even more sharply pictured—in *A. lachesis*, for example, where it appears in minature size.

A less familiar case, and as obviously meaningless, is the resemblance to a cuttle fish, which one finds in the end view of the larva of the crane-fly, *Tipula abdominalis*, Fig. 8. This appearance might conceivably inspire a wholesome dread among some marine creatures—but the fact remains that the present larva lives in wet rotten wood (or under ground) where an octopus-like resemblance could not benefit it. Indeed among insects one may find numerous instances of accidental resemblances. Some pupæ we have already referred to. Others, bombycids, for example, suggest mummy cases, the region of wings, antennæ and tongue, picturing both in form and proportions the Egyptian head-gear and beard. It is improbable, to say the least, that the Egyptians arrayed their dead after the fashion of a pupa to encourage a teleological analogy, for one reason, since the headdress and beard were displayed in a similar fashion during the lifetime of the individual. Striking, too, are pictures which one sometimes finds on the wings of butterflies—among these, as Mr. Beutenmüller showed me, are the heads of French poodles, which appear *en silhouette* on the wings of the orange-colored butterfly, *Colias* (*cæsonia* and *eurydice*). And on the hind wings of the ragged butterflies (*Grapta*), as every one knows, appear commas and semicolons printed in silver upon an otherwise dull-colored wing. In the group of bugs (Hemiptera) one recalls the initial W, which occurs in certain cicadas, and there is the interesting case of the tree-hopper, *Membracis binotata*, to which Professor Wheeler drew my attention. This tree-hopper and its young

FIG. 7. PUPA OF *Feniseca* SP., showing "face."

represent amazingly "a family of tiny birds with long necks and swelling breasts and dropping tails, verily like an autumn brood of bob-whites" (W. H. Gibson), Fig. 9. Had they been twenty times their present size they might have run the risk of being described as mimics!

Among other resemblances of this nature one recalls the spectacles which appear on the neck of the cobra. Then there are the insect,

FIG. 8. "OCTOPUS" SHOWN IN HINDMOST ABDOMINAL SEGMENTS OF THE LARVAL TIPULA.

monkey and human figures in orchids and in various other plants, pictured in flowers, parts of flowers and in fruit. The last sometimes give striking and grotesque forms, as in the case of our common garden snap-dragon, Antirrhinum. Here, Fig. 10, the seed pods look like diminutive human heads which are arranged on the stalk in a way which suggests the poles-of-skulls, or "medicine" ornaments of certain savages. Peculiarly perfect is this resemblance, for there are pictured not merely the cranium and face, but the dried and weathered portions of scalp, eyelids, lips, as well also as temporal sutures. The color of these seed pods, furthermore, is strikingly like that of mummied heads. Meaningless resemblances occur also in various bones, as in the case of the goat skull or the "ear-bone" noted above. Thus, as Hugh Miller long ago discovered, there is a curious human figure in the cranium of a Devonian fish, and the rabbit, even when "dead and turned to dust" is not free from its arch-enemy, for its sphenoid (Fig. 6) pictures the head of a fox so cunningly indeed that this bone has long been used as a scarf ornament for the English hunter.

Instances of this kind need hardly be multiplied. They extend on every side in the inorganic as well as the organic—from the simple cloud figures conjured by Aristophanes or the various forms of weathered rocks (like the "camel of Brignogan"), to the most curious and complicated.

In short, therefore, it is clear that if meaningless resemblances are numerous and striking, one can accept protective resemblance and mimicry only in instances which have been fully demonstrated. And we may in the meanwhile mark as doubtful numerous cases which now pass current in zoological literature. Among these would, I believe, fall the famous leaf-like butterfly, *Kallima,* which Weismann has adopted as the ne plus ultra of protective resemblance, for in the lack of adequate experimental evidence even this form may prove to be a meaningless resemblance, and not the product of selection. That it may be, and probably is, of protective value at the present time can as readily follow from an accidental resemblance which happens to turn out to be valuable as from one which has been the product of

FIG. 9. TREE-HOPPERS WHOSE APPEARANCE SUGGESTS BIRDS. After Gibson in *Century.* (Cut kindly loaned by Dr. Skinner.)

numberless selected variations. In fact, it is quite credible, it seems to me, that accidental favorable variation may have furnished the basis of many a useful resemblance—as some mutationists believe. And there are no peculiar "adaptive characters" in *Kallima* which can safely be construed as more complicated than the meaningless characters of the Taira crab. For in what way is the resemblance of a butterfly with folded wings to a leaf more remarkable than the appearance of a human face on the back of a crab? For the contrast, when dissected, would give us in the one case the characters—leaf-shape, color, midrib, reversed markings (veins) on one side of midrib, concealed legs and antennæ, "petiole," and fungus-like patches, as opposed, in the case of the crab, to the equally complicated characters—human face, color, young, oriental, primitive Japanese, drowned. It is only fair to conclude, therefore, that if a meaningless variation can produce the Taira crab, it might equally well have produced *Kallima*.[4] The conclusion, indeed, that Kallima formed the apex of a series of selected changes, is, on our present evidence as to the habits of this insect, hardly different in kind from the assumption that the present perfection of the skull on the death's head moth is the result of selective

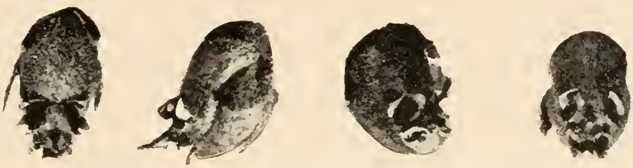

FIG. 10. FRUIT OF THE GARDEN SNAP-DRAGON, *Antirrhinum*.

changes, through whose agency this form came gradually to be avoided and thus secured immunity from, by superstitious man, an important enemy! In fact, in this case, there is actually a stronger body of evidence that the moth is avoided by man than that Kallima is overlooked by birds.

In a word, it is a fair conclusion that our notions of protective resemblance and mimicry are carried in numerous instances farther than the law allows. And one does not have to go far afield for cases in point. Thus the snake's head which is pictured on the wing tip of an East Indian moth, *Attacus atlas*, does not strike one as a convincing case of mimicry, in spite of Weismann's arguments. It is true that the snake is strikingly portrayed, both in color, poise and expression, and we will readily admit that it *might* give a wholesome jolt to some enemy of the moth which happened to see it just at the right angle. But the picture in this instance is not more striking than many of the meaningless resemblances we have quoted (*e. g.,* the French poodle pictured on the wing of Colias), and I think we may reasonably demand definite experimental proof before accepting the "mimicry." In certain other instances one can not feel assured that the resemblance is of actual value to the "protected" form. As an instance of this,

[4] In this connection, *cf.* a note in *Science*, Vol. XVI., p. 832, in which the present writer comments upon the scantiness of evidence as to the protective value of the characters of *Kallima*, and notes the appearance of this insect on and near leaves which it in no way resembled.

I recall the living *Ichthyophis,* the curious burrowing salamander, which I once had the opportunity of observing in Ceylon. This is surprisingly like a worm in many regards, yet a mimic it can not be, since it could derive no profit from the resemblance, the worm being infinitely less protected than itself. If any mimicry could exist in this case it is clearly in the opposite direction, the worm mimicking the salamander, but this possibility is precluded since the mimicking form is infinitely more plentiful than the mimicked, and, most significant, neither form is apt to expose itself in a light where the resemblance would have any value. None the less the mutual resemblance is quite striking—in shape, proportions, size, color, annulation, movements, position of vent, etc. Yet we can only interpret it as due to parallelism. And if this is the case, may not parallelism, *i. e.,* similarity in structures due to similarity in habits, not mere accidental resemblance, be taken as a further danger in interpretation.

For the rest we may query, as others have done, whether the importance of protective coloration and mimicry may not be still further diminished when we eliminate our anthropomorphic conception of the senses of the lower animals. For we may reasonably harbor the suspicion that colors and patterns, which to man seem protective, are by no means as valuable as protection against the keener and more specialized visual impressions of the lower animals. For just as "scent" perception in certain invertebrates, as in various moths, is immeasurably refined, far more so than we are in the habit of conceiving the scent-sense, so also there may have been developed a special sense for detecting the most subtle differences in color, texture, form in those animals which prey upon mimetic and protectively colored forms. Indeed, such a view is the less unreasonable when one considers the condition of the optic centers and end organs in those vertebrates, teleosts, reptiles, amphibia, birds, which have most to do with creatures in which protective coloration and mimicry is supposed to occur most abundantly. And it is not beyond the pale of possibility that the predatory forms have evolved habits in connection with sense-organs which would cause them to distinguish more promptly the protected forms than those having bright and obvious colors. It is in this direction that we have need of close observation and critical experiment.

THE HISTORY OF SCIENCE—AN INTERPRETATION

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IN the recent discussion of the ways and means of making more efficient use of science in educational work, one suggestion keeps coming repeatedly to the front—perhaps more frequently than any other. It is this: That the history of science be made more prominent in the course.

This suggestion has been made from a number of different points of view. For example, some claim that the stories of the lives of the heroes of science furnish powerful stimuli toward arousing interest in and enthusiasm for the study of science. Others urge that the history of inventions may be used to great advantage in linking work in science with social and economic life, thus adding a touch of human life to an otherwise rather abstract and impersonal subject. Still others hold that scientific concepts can not be clearly formed without tracing them from their origin through their development to their present condition.

The importance of recognizing that science is not ready-made, fixed and finished in form and matter; the delight that young people feel when they are shown that the field is open before them, so that they too have a chance to help in the building up of science; the pleasure of knowing that he who works in science is dealing with a growing thing—all of which may be obtained from a study of the history of science—are all put forth as reasons for our paying attention to this side of our work. To one who thinks over these various suggestions, it must appear that they are not independent of one another. Hence, because of the growing importance of this matter of history of science, it becomes of interest to see if a more general justification for its introduction can not be found—one that includes all the others as special cases, and at the same time points out the way in which this history should be handled to enable it to produce the most valuable results. If we would attempt to do this, we must first agree on what we mean by history, and what by science; since each of these words covers such a multitude of sins that its meaning is not sufficiently definite for our purpose.

I. The history whose study lends power to the teaching of science is, naturally, not the thing that is popularly known as history; namely, political history. It is evidently of small interest to science to know to which royal family the king at any given period belongs; nor is science particularly concerned with the list and the peculiarities of the wives of Henry VIII. Science does not even care tremendously whether Marie Antoinette spent her summers at Versailles or at Medicine Hat; nor yet whether the jewels of the mother of the Gracci were real diamonds or only paste. This sort of information, which seems to be of paramount importance in what popularly passes under the name of history, has no part or place in the type of history in which science is interested.

Just exception might be taken to any attempt on the part of a specialist in science to define what constitutes the right sort of history—even though it be history of science. Fortunately, however, some specialists in history have given us a definition of history to which the scientist may give a hearty consent. Traces of this interpretation of history may be found in a number of historical works of the past half century, but it has only recently found extended expression in the writings of Carl Lamprecht and his followers. A good summary of the philosophy of this school of historians was given by Professor Lamprecht in a course of lectures delivered by him in 1904 both in St. Louis and in New York. These lectures have been published in English under the title "What is History?"

For science the most important points in the doctrines of this Leipzig school seem to be these: (1) That history—real history—consists in the portrayal of a series of culture epochs; (2) that the character of these culture epochs is determined by the higher spiritual or psychic attitude of the more gifted of the people, and not by the whims and idiosyncrasies of a line of sovereigns; (3) that the most telling criterion of the psychic attitude of a people at a given epoch is found in the productions of their creative imagination. Hence, if we would understand the nature of the culture of any people at a given epoch, and trace the mechanism of its changes to the next epoch, we must study first of all the products of their creative imagination, *i. e.*, their art, their poetry, their philosophy, and their science. Important, but of secondary importance, are the political, social and economic conditions. In other words, the psychic character of any nation at any epoch is determined by the spiritual attitude of the best people; and this condition is expressed more directly in the works of their creative imagination, and less directly in their political, social and economic conditions.

To sum up this first point, then, we may say that the sort of history needed by science is a portrayal of culture epochs, their character having been determined by a study of the works of the creative imagination of the best people of the time; and hence the importance of the history of science is derived from the fact that science is one of the productions of the creative imagination, and therefore the study of its history, when properly conducted, should shed immediate light on the problem of determining the nature of the psychic condition of a people at any epoch, *i. e.*, the character of the culture epoch, and of discovering the mechanism of the change from that epoch to the next.

II. But, supposing this to have been accomplished—which has not yet by any means been done—what good will result? Why should we care to gain an insight into the psychic development of a nation?

One immediate consequence of this sort of historical study would be the much-desired humanizing of science; for we should be compelled to recognize the various ways in which science has cooperated with the other phases of human activity in bringing us into our present condition. Still another fruitful consequence would be the gradual extinction of the pernicious notion that scientific conclusions are final—that the *ipse dixit* of science permanently settles all controversy. Other specific benefits might be mentioned: but in this case also all roads lead to Rome, since the central idea of all the reasons for the study of the sort of history that has just been defined is the idea of the analogy or correspondence which exists between the development of a nation and that of each individual of that nation. It is the idea expressed in the *Gliedganzes* of Froebel, in the parallelism between the ontogenetic and the phylogenetic series of Baldwin, etc. It is the idea expressed by Lamprecht when he says: "History in itself is nothing more than applied psychology."[1a] According to this idea we must study the past evolution of science in a people or in a type of civilization in order to understand the evolution of science in the present individuals of that people or of that type of civilization: and conversely, the psychological study of the growth of scientific concepts in the individual sheds light on the scientific growth of the nation.

The meaning and the importance of this idea, not only to teachers of science but to teachers generally, have not yet become fully apparent. Some go so far as to ridicule it. Thus in a very able address on the "Order and Development of Studies suited to Each Stage," Superintendent Wm. E. Chancellor, of Washington, D. C., reaches the following conclusion:[1]

> In this presentation, I have absolutely rejected two familiar theories; that the child must pass through the history of the race, and that he must be prepared directly for participation in the affairs of the modern world. . . . And I have said in terms as unequivocal as they are brief that, to my thinking, as I view the external world of reality and the real world of the soul, we shall find our solution in a genetic psychology that reveals the processes and stages, the functions and the interests, the motives and the ideals, and the principles of the soul as it journeys and sojourns from birth to death.

[1] Report of the Department of Superintendence, 1907, p. 80.
[1a] "What is History?" p. 29.

He does not seem to see that psychology will become more complete and more able to furnish the solution so earnestly desired by all, the more it is studied as applied psychology in history as well as applied psychology in the individual. The two are mutually complementary; by neither method alone can we hope to reach as deep an insight into the meaning of history and the growth of the individual as we can if we use both methods, and continue to work till the results obtained from the two are in substantial accord.

An appreciation of this symbolic relationship, analogy, or correspondence between the whole and the part, the individual and the nation, opens up to the teacher who yearns for the opportunity of carrying on research work a comparatively new, untilled, almost unexplored region for fascinating investigation. The complexity of the problems to be solved, the great value to humanity of the solutions when scientific, and the magnificent opportunities for self-development, for broadening of the personal outlook and for obtaining a clearer understanding of present conditions all offer alluring inducements to every growing man or woman to take part in this new enterprise. By such labor—painstaking, patient, unprejudiced, in a word, scientific—every one may help in gaining for all a better and more adequate interpretation of the past of our civilization and of the present nature of the individual than any hitherto acquired.

In addition, all such study, leading as it inevitably must do to a deeper insight into the realities of the life of mankind and of man, can not fail to inspire the open-minded and earnestly seeking soul with an ever keener appreciation of the majesty, the mystery and the final beauty of humanity. As Lamprecht, after outlining some of the problems of universal history, fitly says:[2]

> On entering the limitless field of universal history, the speaker feels it incumbent upon him to declare that he does it with the greatest diffidence. Whoever thinks along historical lines and has a fair knowledge of some period of universal history, *e. g.*, of the history of a single nation, will be overcome with a feeling of awe at the prodigious many-sidedness and the endless significance of human activities. And, as a result of this feeling, gentle stirrings of the mind are aroused, which take form in sacred admiration of the achievements of mankind; a noble yet dangerous devotion to the grandeur of the human race takes possession of us. . . . We can not enter into problems of universal history, unless we do it with the earnestness of religious feeling, else the standard of the methods which may be used will be completely obsolete and will consequently fail in the application.

This second point may be most fitly summed up in the words of Froebel:[3]

> Every human being who is attentive to his own development may thus recognize and study in himself the history and the development of the race to

[2] "What is History?" p. 185.

[3] "Education of Man," p. 41.

the point it may have reached, or to any fixed point. For this purpose he should view his own life and that of others at all its stages as a continuous whole, developing in accordance with divine laws. Only in this way can man reach an understanding of history, of the history of human development as well as of himself, the history and phenomena, the events of his own development, the history of his own heart, of his own feelings and thoughts; only in this way can he learn to understand others; only in this way can parents hope to understand their child.

III. Having now defined what sort of history is under discussion, we may now turn to ask what we are to understand by science. This term is generally considered to be synonymous with classified or organized knowledge. But if we confine ourselves to this meaning of the word science, and if we think that we are studying the history of science when we study the gradual accretion of classified knowledge, we shall not be able to get from our labors much illumination on the subject of culture epochs; for in the early stages of civilization, in the ruder culture epochs, we find no classified knowledge that would now be recognized as science—no laws of nature, no great abstract principles. Yet there must have been, in those barbaric and primitive times, something that bore the earmarks of science—something which could serve as a means of identifying the nature of the culture epoch from the point of view of science. What was this, and how discover it? Is there any characteristic of scientific work—any typical factor which always appears in a scientific investigation, and whose rudiments may be discovered even in so-called uncultivated epochs and in apparently scienceless eras?

Recently it has been suggested that the scientific status of a nation at any epoch may be determined from a study of the kind of problems over which the people puzzled and the way in which they solved them, *i. e.*, problem-solving furnishes a criterion of culture from the point of view of science. This criterion is evidently capable of universal application, since every nation and every individual of every nation has had to meet and to solve problems. Furthermore, problem-solving always involves, to a greater or less extent, the use of the creative imagination; hence this criterion justifies itself in the light of the definition of history just given, since the kind of history that is needed has to be studied through the expressions of that imagination.

One thing more is necessary in order completely to define our criterion of scientific culture, and that is a statement of the conditions under which problem-solving may be classed as scientific. It is probably not necessary here to more than state those conditions, since their meaning is now so well understood. A problem has been solved scientifically when its solution has stood the test of the most unprejudiced and relentless criticism both from the side of reason and from that of experiment; and also, when the limits within which its solution is valid have been determined. The importance of this function of the critical faculty in scientific work is too often overlooked; for it is not always so agreeable to remember that criticism is as fundamental a necessity for creative work as is imagination. Since this interplay between the imaginative and the critical faculties is not so well known as the scientific method, we may say that a problem is solved scientifically when its solution has been obtained by the scientific method.

It is important to notice that this definition of science as problem-solving shifts the emphasis in the scientific work from classified knowledge, which is the result of the process, to the process itself, by which the result is obtained. It must also be noted that this definition is more comprehensive than that of classified knowledge, since it may include the operations of a savage in learning to fish and hunt, as well as work by this method in subjects not ordinarily considered parts of science, like classical philology, higher criticism, philosophy and even commerce and politics—not to mention theology.

This third point may now be summarized as follows: The thing whose history is to be studied under the title of history of science is not classified knowledge, the finished product; but it is problem-solving by the scientific method, that active creative process which involves the properly coordinated use of both the imaginative and the critical faculties.

IV. When we attempt to interpret the history of science in the light of the principles just explained, we are bewildered by the complexity and the magnitude of the task. How may any one ever hope to unravel the tangled mass of material that confronts us, or to bring order out of the apparent chaos of problems which have engaged the attention and taxed the energies of mankind. Consider how intricate and how seemingly inexplicable are the problems that overwhelm each individual: how much greater must be the intricacy and the almost hopeless mystery of the problems that vex an entire nation at any epoch! Fortunately, some progress has been made since the time of Hesiod, who wrote: "In the beginning there existed Chaos," the modern view having been expressed by Chamberlain[4] in the words: "No. Chaos has always been at home only in the human mind, never elsewhere." Hence, it is no longer allowable to regard the attempt to find a rational interpretation of the history of science as foolhardy.

A good deal of progress has already been made toward the production of a history of science along the lines here indicated, and a number of practically valuable conclusions have already been reached. For example, the recent discussions of the origin of problems is tending to clarify our notions of how science (problem-solving) originates. This is evidently one of the first phenomena demanding interpretation at the

[4] Grundlagen des neunzehnten Jahrhunderts," p. 737.

hands of the historian of science. In this matter the historian of science may be of great assistance to the psychologists among whom the discussions are being carried on; since, because of the analogy of the individual and the nation, the origin of a problem in the one may throw light on the similar process in the other.

This may be illustrated by numerous examples. Thus, some psychologists claim that the problems of science grow out of the practical needs of social and economic life. For example, to the primitive man the problem of catching the fish becomes real and definite because of his hunger. In like manner, the problem of the steam engine developed only after there was urgent need of such a machine for mining purposes; and the problem of the electric telegraph was defined by a marked social demand for a quick method of sending messages. The modern inventor finds the impulse to invention in his hope of gaining material reward for a more efficient machine, etc. But while this explanation of the origin of problems may do for those that fall within the realm of applied science, some think that it is not so useful when applied to the problems of pure science, like that of the motions of the solar system, the phenomena of universal gravitation, etc.

In order to account for the origin of this latter type of problem, it has been claimed that the prime factor in the definition of the problems that go to make up science is not to be found in the practical or concrete external situation, but rather in some internal ideal or desire or feeling with which an individual becomes inspired, he knows not how or whence. According to this view, an individual may notice an external phenomenon over and over again without its defining in him a problem. It is only when he notices in the phenomenon two or more factors that do not seem to him to be in harmony—not to accord with some cherished or imagined ideal—that a state of curiosity or of mental tension is induced; and when this condition is reached, he has a problem defined within him, which, if he have any real scientific spirit, does not suffer him to rest until his curiosity is satisfied or his mental tension eased. When this latter state is reached, he is said to have found an "explanation," and the problem is for him solved.

These statements are, of course, but the crudest possible descriptions of but two of the points of view from which the origin of problems has been approached. It will require considerable discussion and study before the whole matter will be cleared up in a tolerably satisfactory manner. But even though the question is far from settled, two important conclusions follow at once from either or both of the points of view just outlined. The first is this: Science is not the source of the progress of civilization. It is rather the faithful handmaid who helps us truly to satisfy the practical needs of society as they become manifest, and to achieve the purposes, ideals, or whatever they are, that spring up within us somehow to disturb our peace of mind. In other words, scientific problems, and therefore science, originate in either the external situations of concrete experience, or in our ideals, or in both, and hence these latter and not the former are the real source of progress. Thus progress is simply a process of self-realization of society, and science is a powerful tool for the successful carrying on of the process.

The other important conclusion applies to the teaching of science, and it is too patent to need more than statement. It is this: Science in the individual child arises, as it has in society, from either the outer surroundings or the inner purposes of the child. Unless the problem whose partial solution we wish to teach the child spring up within him from either outer or inner necessity, the problem is not his own problem, it is not real to him, and, therefore, its solution is not real to him and so makes no impression. Hence the skill in teaching science is a skill in presenting facts in such a way that the problems whose solutions we wish to teach become the child's own problems. It is thus a skill in causing problems to become defined in the child's mind. The science of the child, like the science of humanity, consists, then, in his own solving of problems that seem to him to arise naturally, either out of his own practical necessities of his own social and economic life, or out of his own purposes, ideals or aspirations that seem to him to have sprung up spontaneously within him. This sort of teaching is quite a different matter from that which generally passes under the name of science teaching, namely, learning the laws and principles of science from a book by memory, with some laboratory and lecture experiments thrown in gratis by way of illustration.

V. So much for the light thrown on present conditions by the study of the origin of scientific problems. But one other example will be added to show the sort of interpretations that may be reached through a study of the way in which various peoples have used their creative imaginations in solving their problems after they had once become defined. For this purpose a problem in applied science will be more illuminating, so we will take this: How was the problem of satisfying the human need of worship solved by the Greeks and by the people of the middle ages? Both expressed their solutions in concrete form in buildings, which still stand as permanent expressions of the workings of their respective creative imaginations.

The Greek temple was a larger and somewhat idealized man's dwelling—a home for deified men and women. It was limited in design to straight lines, since the idea of a curved arch had not yet been achieved in practise. Yet it was a perfect realization of the conception which it was intended to embody—a limited conception, since the idea of deity which makes God to consist of heroic or idealized men and women must necessarily be cramped and limited. The Greek temple was not intended for public worship of an invisible God, but for the actual residence of their many humanized gods. From this it may appear that their religion was man-made, *i. e.*, that it was no real religion, but only a philosophy; and so we are in a better position to comprehend the classical ancestor worship and the Lares and Penates. When we start from this center we may also get a better insight into the Greek character as a whole.

The middle-age cathedral, on the other hand, bore no resemblance to the dwellings of men. It was a lofty edifice with numerous spires pointing to heaven. It was built for public worship of one God, and was adorned at every point with a richness of tracery and design that would bewilder the observer of to-day were it not so harmonious in all its parts. The conceptions embodied in it are wholly distinct from those ultimated in the Greek temple, showing what a complete and fundamental change in the idea of divinity had come over mankind. The cathedral was not the perfect realization of a limited ideal, but the imperfect realization of an unlimited ideal; and this shows a vast expansion and elevation of the conception of religion—an expansion and elevation that must be ascribed wholly to the christian religion.

Furthermore, the effort to realize these expanded and elevated ideals led to the definition and the solution of numerous practical problems in applied science. The construction of a Greek temple is a simple engineering feat when compared with that of a Gothic cathedral. The solution of these engineering problems lead to the definition of others; and so we see in the middle ages a great development of skill in all sorts of manual arts, carving, metal working, stone cutting, weaving, printing, etc., all before modern science made any pretense of being extant.

Time forbids the following of the argument into detail. There are just two important conclusions that seem to be justified by this comparative study. I will, in closing, state them; and leave the reader to find out if, after further study, he too finds them justified. The first is this: Since Christianity was the source of the ideals that led to the construction of the cathedrals; and since this work and these ideals led to the definition and solution of many problems in applied science; and since the solution of problems in applied science precedes and prepares the way for the definition of problems in pure science; therefore, we may make the hypothesis, subject to further verification, that modern science owes its origin from the side of the imagination to Christianity. Hence the so-called warfare of science and religion is but a sham battle between science and dogmatic theology—between reason and unreason. Modern science is, from this point of view, really the child of Christianity.

The second conclusion that seems justified is no less important for the science teacher. It is this: Since the dawn of modern science was preceded by the solution of a great number of practical problems, which arose from the practical needs and the ideals of the times, and which developed in humanity a great deal of skill in the handling of tools and the mastering of matter, the course of the child in learning science should be similar. Hence, it is unscientific to try to teach modern science to a child that has not been prepared for it by a symbolic middle-age training in the mastery of tools, brute force and concrete matter.

No one can realize more fully than the writer the inadequacy of this discussion of this mighty theme. The same theme has been handled far more completely by Carlyle in the following short paragraphs from his review of the Corn Law Rhymes:

> Nay, it appears to us as if in this humble Chant of the Village Patriarch might be traced rudiments of a truly great idea; great though all undeveloped. The Rhapsody of "Enoch Wray" is, in its nature and unconscious tendency, Epic; a whole world lies shadowed in it. What we might call an inarticulate, half-audible Epic! The main figure is a blind aged man; himself a ruin, and encircled with the ruin of a whole Era. Sad and great does that image of a universal Dissolution hover visible as a poetic background. Good old Enoch! He could *do* so much; was so wise, so valiant. No Ilion had he destroyed; yet somewhat he had built up: where the Mill stands noisy by its cataract, making corn into bread for men, it was Enoch that reared it, and made the rude rocks to send it water; where the mountain Torrent now boils in vain, and is mere passing music to the traveler, it was Enoch's cunning that spanned it with that strong Arch, grim, time-defying. Where Enoch's hand or mind has been, Disorder has become Order; Chaos has receded some little handbreadth, had to give up some new handbreadth of his ancient realm. . . .
>
> Rudiments of an Epic, we say; and of the true Epic of our Time,—were the genius but arrived that could sing it! Not "Arms and the Man"; "Tools and the Man," that were now our Epic. What indeed are tools, from the Hammer and Plummet of Enoch Wray to this Pen we now write with, but Arms, wherewith to do battle against UNREASON without or within, and smite in pieces not miserable fellow men, but the Arch-Enemy that makes us all miserable; henceforth the only legitimate battle!

PHYSICS [1]

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IN the upbuilding of all the great and diverse departments of thought, characteristic methods have arisen which the human reason has found best suited to the pursuit of the many phases of truth which it seeks. In the perfection of methods and resourcefulness in applying them, no age has been more fertile than our own. Yet one ever present danger to the orderly and symmetrical development of modern thought, is that those working in different fields for its advancement may lose touch with one another, and the interchange of methods and results so essential to balanced growth be neglected.

If in such a course of lectures as this, each lecturer coming from a neighboring or distant field succeeds in showing the nature of the evidence he has been taught to consider, his methods of weighing it and some of his results, the university will be the gainer in increased knowledge, in broadened sympathies and in a deeper realization of the wholeness of truth.

It is doubtful if our understanding of the unity of external nature can ever be illuminated by the lamp of any one of the natural sciences. The division of nature into separate departments of study has been an intellectual necessity caused by the greatness of the task.

The easiest cleavage would separate the animate from the inanimate, the biological from the physical sciences. This cleft, the first to form, will be the last to close; for to define the precise relations of life to matter is now one of the most intricate and difficult problems in the whole range of human endeavor. Who will fundamentally answer the question, how does a seed become a tree?

The phenomena of inanimate matter are involved and complicated in the extreme, but those of living matter are even harder to understand. The outward or objective manifestations of life are of a material or physical character, and the purpose of the biologist is to apply to them the principles of physics and chemistry as far as these will carry him, and in many directions they have already carried him far. When, however, we consider the subjective phenomena of life, or consciousness, the question seems to me a metaphysical one and we are without assurance that physics and chemistry can lead us beyond the boundaries

[1] A lecture delivered at Columbia University in the series on science, philosophy and art, as the opening lecture in the natural science group, October 23, 1907.

of it. Indeed, just where physics and chemistry leave off, I feel a real and deeper problem begins. If so, the question lies at present beyond the reach of natural science which biologist and physicist alike interpret as the science of matter and energy.

In what follows I shall try to review very briefly the principal ideas upon which modern physics rests and shall say something about where we think we have arrived in our search for knowledge. I need scarcely remind you that in the natural sciences as in more practical affairs, *how* we have arrived is as important as *where* we have arrived. I shall therefore spend some time in presenting detached fragments of the experimental evidence and inferences upon which certain conclusions are based, hoping in this way to illustrate some of the constructive methods of reasoning employed in research.

The ideas which underlie all our thinking are space, time and inertia or mass. With space and time as a background, the physicist must pursue inertia and everything related to it, along every conceivable path. In this pursuit he comes upon four ultimate though related conceptions: matter, ether, electricity and energy.

The historical development of these conceptions can not even be sketched in such a lecture as this, but it should be remembered an important part of our present knowledge of matter, and nearly all that we know of the ether and electricity has been gained not immediately, but by inference. In so many cases we see or know directly only the first and last link of a chain of events and must search by indirect means for the mechanism lying between.

At bottom, I suppose, the ether, electricity, force, energy, molecule, atom, electron, are but the symbols of our groping thoughts, created by an inborn necessity of the human mind which strives to make all things reasonable. In thus reasoning from things seen and tangible, to things unseen and intangible, the resources of mathematical analysis are applied to the mental images of the investigator, images often suggested to him by his knowledge of the behavior of material bodies. This process leads first to a working hypothesis, which is then tested in all its conceivable consequences, and any phenomena not already known which it requires for its fulfilment, are sought in the laboratory. By this slow advance a working hypothesis which has satisfied all the demands put upon it gradually becomes a theory which steadily gains in authority as more and more new lines of evidence converge upon it and confirm it.

If we now consider more closely the nature of the conceptions, matter, ether, electricity and energy, we shall later find that matter, ether and electricity possess some attributes in common, and if we take careful heed to what we shall understand by the word, we may call them substances. Energy appears as the measure of their possible interactions.

Taking energy first: All the numberless changes we see taking place in the universe are, we think, manifestations of the interactions among matter, ether and electricity. With every changing aspect of nature, energy is passing from body to body and undergoing incessant transformations, but its amount is always measurable by the work it may accomplish when harnessed.

Our knowledge of the uncreatable and indestructible character of energy has given us a universal test which we may freely apply to all phenomena to prove our knowledge of them. For when the required energy relations are not satisfied by our explanations, it means we have not got to the bottom of the case, but must strike deeper in to realize the whole of the concealed mechanism.

Charmed by the simplicity and sweep of the law of the conservation of energy, a small school of physicists, who have mostly entered in by the door of physical chemistry, have frankly set energy before inertia and have endeavored to deduce matter and all else from it. This can of course be done, for physics has become a body of thought so closely knit together that all things in it are somehow related. Seen broadly, however, the new method has few obvious advantages over the historic procedure and not a few evident defects.

Matter has two indisputable hallmarks, two properties in the possession of which all the infinitely varied forms of matter unite, inertia and weight. By inertia we mean that active resistance shown by every piece of matter to any effort to change its motion; while the mutual attraction between all material bodies, according to which all matter strives to collect itself into one huge compact lump, we call gravitation. The gravitational pull of the earth upon a portion of matter is its weight. If we find anything in the world, however strange, which possesses both inertia and weight, we may call it matter without further examination.

The ether which surrounds and encloses all our universe we came first to know as the bearer of waves of light and heat. Ever since that time we have known it to possess inertia; for no medium devoid of inertia can carry forward a wave motion.

Thus the ether has one of the hallmarks of matter. Has it also weight? This we can not hope to know until we find some way as yet undiscovered to alter the natural distribution of ether between two portions of space. Here it should be remembered that the weight of gases was first proved after the invention of the air pump and barometer. But, alas! how shall we go about building an ether pump when all material walls seem more porous to the ether than the coarsest sieve is to air? And worse, the ether appears to be incompressible. The question of weight is thus at present in abeyance and we leave it.

Of the properties of electricity alone, it is still difficult to speak. The subject is easiest approached from the relations of electricity to ether on the one hand and the relations of electricity to matter on the other. It is in this last and more complicated phase of our subject that the most brilliant advances have recently been made.

To state the case between electricity and ether, we must begin with Faraday and some of the mental images he formed of the connection between them, which have proved at once the most simple and useful aids to thought to be found in the whole history of physics. Faraday realized as well, perhaps, as we do to-day that electricity could no more be made outright than could matter. The utmost which could be done was to separate positive and negative electricity. If, therefore, any one exhibited a positive charge, there was somewhere in the universe an equal negative charge, to which it was drawn by invisible means across the intervening space.

Faraday maintained the forces of attraction were due to some kind of strain in the ether lying between. To picture the more vividly to himself and to others, the character of the stresses in this medium transmitting the force which one charge exerts upon another, he supposed contractile filaments called lines of force to traverse the ether between the charges. To make the case more definite he gave direction to these lines, assuming that they originated on the positive charge and terminated on an equal negative charge near-by, or far away, according to circumstances.

The motions of electric charges when free to move, and the distribution of stresses in the ether round-about, show that all happens as if each line of force were pulling like a stretched elastic thread to shorten itself and draw the charges together, and at the same time unlike any elastic thread we know, it was repelling or pushing sidewise at the other force lines near it.

If a charge of positive electricity be given to a metal sphere, and the negative charge from which it has been separated be dissipated to remote bodies or be carried so far away that its position is no longer of any immediate importance, lines of force will start from the spherical surface of the conductor in all outward directions, and will be precisely radial. As many lines will leave from any one half of the sphere as from another. This equal radial arrangement of the lines of force is produced by the sidewise shoving of each line of force upon its neighbors until the stresses in the ether at the bounding surface of the metal are equal on all sides.

If now the metal sphere with its charge be put in steady motion, it will carry its lines of force along with it, and if the motion be not too swift, all the lines of force will continue radial. But with this motion of the lines of electric force through the ether, a wholly new and additional ethereal force appears—a magnetic force which did not exist when the charge was at rest. This magnetic force is always at right angles both to the lines of electric force and to the direction of their motion, thus encircling the moving charge. The planes of these circles are perpendicular to the straight path along which the charge is traveling.

As long as the motion and charge remain uniform there will be no change whatever in this magnetic force except that it keeps abreast of the sphere as do the moving lines of electric force on which it depends. As soon as the motion ceases, the magnetic force disappears and soon all is as it was before the motion began. But while the sphere is starting or stopping, before it has reached its steady motion or while it is coming to rest, the electric and magnetic forces are undergoing readjustment and this disturbance spreads outward through the ether with a speed precisely equal to the speed of light. Nor is this a chance agreement, for we now know that light consists of nothing more than very rapidly and periodically changing electro-magnetic forces traveling out through the ether from a particular source of electric disturbance, called a luminous body. The ethereal phenomena we have noted around a moving charge faithfully repeat themselves about a wire carrying an electric current and it was here that Faraday found them.

To the mental images of Faraday—these lines of force which helped him to grapple with the unseen, to form working hypotheses, to experiment: to these Maxwell applied the powerful resources of mathematical analysis and reared the splendid structure of the electro-magnetic theory. Now that the work is done we may let fall the scaffolding which Faraday's vivid imagination supplied, but we could not earlier have done without it. Here we have the whole chain, mental image, hypothesis, experiment, theory.

As we now take up what we believe to be the relations of electricity to matter, we come in places upon slippery ground and the bases of our faith rest on recent foundations.

At the outset we encounter one striking difference between electricity and matter. Every free charge exerts a force upon every other charge in the universe, just as every particle of matter exerts a force on every other particle of matter however distant. But with matter the particles are invariably urged toward each other while electric charges may be either drawn together or forced apart, depending on the kinds of charges. We have both positive and negative electricity, but only one kind of matter.

Just how these two kinds of electricity are different we know little beyond the invariable law that positive attracts negative and repels positive. In some ways positive and negative electricity resemble right- and left-handed things. If the same number of right- and left-handed turns be given to a screw, one hand will precisely undo the work of the other. If the right and left hands be brought together they fit part for part, but two right gloves are a poor pair. On the contrary, there is no right and left to gravitation. Two pieces of matter always fit in the gravitational sense.

The bald statements of the laws of gravitation and electric force bear a strong resemblance to each other. The laws tell us how the forces *vary*, but reveal no hint of the machinery by which they *act*.

Gravitation was the first force man encountered and it is still the one he knows least about, for we have got no farther than where Newton left it two and a half centuries ago. We have some inkling of the possible machinery by which one electric charge acts upon another at a distance and we feel nearly as sure that the push or pull is carried by the ether as that the pull of a horse on a cart is through the traces which bind him to it. With gravitation the case is very different, for we have not as yet the slightest valid conception of *how* the pull of one mass upon another is conducted across the intervening space, nor *what* conducts it. We can get no farther until the speed with which gravitational disturbances travel has been measured, and no one at present seems to know how to go about making such an experiment.

One further difference between gravitation and electric force. The force of attraction or repulsion between two charges of electricity is diminished by replacing the free ether between them with any material medium, but the force of gravitation between two bodies remains constant as long as the distance remains constant, and intervening masses are powerless to shield or to alter it. Hence we can not yet attribute the gravitation of matter to any electricity which may be contained in it, nor prove the ether to be the medium through which the force acts.

Gravitation is still unconnected, unattached to anything else in nature; as independent as Mr. Kipling's "cat that walked by himself, and all places were alike to him." It is still the stumbling block to the physicist which it has been these many years. How can he explain a universe when he is unable to give a reasonable account of the cement which holds it together?

Of the intimate association of electricity with matter we have learned much from careful study of the processes of electric conduction in solutions and gases.

When a simple chemical compound (and it should here be borne in mind that the molecule of a compound is built up of atoms of at least two different kinds)—when a simple chemical compound, hydrochloric acid for example, is dissolved in water and an electric current is passed through the solution, the products hydrogen and chlorine of the decomposed acid appear in definite proportions at the points where the current enters and leaves the liquid—the chlorine where the current enters, the hydrogen where it leaves. We know this current to consist of processions of single charged atoms, a disorderly march, perhaps, with a crowd of bystanders obstructing the way, but the movement is always forward, each constituent of the broken molecule carrying a definite electric charge. These processions are always double, the atomic carriers of the positive charge moving in one direction, those carrying the negative charge in the other. The same quantity of positive electricity is carried by one procession, as negative electricity by the other. We have not only measured the charge carried by a single atom, but the average speed with which the atoms traverse the solution. It has been found, further, that atoms of the different chemical elements having the same mating value, technically called valence, always carry the same unvarying charge, whether the atoms themselves be light or heavy. These charged atoms, in some cases atom groups, are spoken of as *ions.*

Such electrolytic experiments as these have led to two surprising results. First: no electric charge smaller than that carried by an atom of the hydrogen valence has yet been found. Second: all other small charges are exact multiples of this value.

We have long been familiar with the idea of atoms of matter, but here for the first time we come across something which looks very like an atom, or natural unit, of electricity. The justification for calling it an atom of electricity is like the argument for the atom of matter. Moreover, we know some eighty different kinds of material atoms, but only two kinds of electric atoms, a positive and a negative. Thus the electric atom of the two has the greater claim to simplicity. When we speak of an electric atom disregarding for the time the matter associated with it, we call it, not an *ion,* but an *electron.* Evidence will later be given suggesting ways by which we may wrench a negative electron wholly free from matter, and experiment with it in its detached and pure state.

We are now in a position to consider the rôle electric forces play in holding atoms together within a compound molecule, for, from the foregoing, it appears when a molecule is broken in two, the fragments are always found equally and oppositely charged, and they doubtless held these charges within the molecule. But the distance separating the two parts was then so small that all the lines of force from the positive charge ended at once on the equal negative charge, and no force lines strayed beyond the molecular boundary. Hence no evidence of an electrical charge could be found in the ether outside the molecule. It seems probable, therefore, that the electric force between the atoms of matter in the molecule supplies the chemist with the cement he has long called *chemical affinity.*

The ratio of the electric charge to the mass of the particle on which it rides (in our processions) has come to be one of the most important quantities in physics. As we know both the quantity of matter and quantity of electricity transferred by a given electric current, we can express this ratio for each chemical element. Hydrogen gives the largest ratio found in solutions.

Systematic study of the conduction of electricity in gases is of more recent origin, but the knowledge gained from it not only confirms the ideas formed to explain conduction in solutions, but has very widely extended and simplified them. The chief difference between electric conduction in solutions and conduction in gases arises from the large number of broken molecules or ions always present in solutions. These require only the presence of an electromotive force to start them marching, but a gas, in its natural or non-conducting state, contains very few ions, not enough to support even a very small current, and for this reason gases are insulators.

In gases, however, there are many ways of making ions, X-rays, radium rays, rays of ultra-violet light on metals, combustion in flames, white-hot bodies of every sort will do it. But there is one method which depends on the violent collisions of ions with molecules which is so objective in its form I can not forbear attempting to describe it. It is also the method which leads us to cathode rays and much more.

Imagine, then, a glass tube into each end of which a conducting rod carrying a small metal disc is sealed. These rods may at will be connected to the terminals of a battery. If while the tube is filled with a gas, in its non-conducting state, the battery be applied, the very few ions always present are set in motion, but the too frequent collisions in the swarm of neutral molecules which obstruct the way prevent the moving ions from attaining more than moderate speeds.

By connecting the tube to an air pump as many as we like of the interfering molecules may be removed. As more and more gas is drawn out of the tube, the moving ions encounter fewer and fewer collisions and in consequence attain higher and higher speeds, as small shot might fall through a gradually dispersing swarm of bees poised in midair. The longer the pumping is kept up the greater the maximum speed of the ions becomes and the more violent are the collisions which do occur. When nearly all of the gas has been drawn out of the tube, a stage is reached where the encounters between flying ion and indifferent molecule become so violent that molecules are shattered and new ions produced, which in their turn work more destruction.

When this stage is reached, the gas is a good conductor, but if the pumping be carried too far, a second stage appears in which the encounters are too few to make enough new ions to support the current, and the gas finally ceases to conduct systematically. It is near the end of the conducting stage that the much-discussed cathode rays appear. They depart from the cathode or metal disc in the end of the tube connected to the negative side of the battery.

The extraordinary resourcefulness, shown by the leading workers in this field of recent enquiry, in untangling the complex snarl of phenomena presented, marks a very great achievement. So inspiring from the human side as well as the physical has been this unequal contest of man with nature, of mind struggling against disorder, and so bravely done, that I ask your indulgence while I try for a few minutes, fragmentarily, to describe one or two fundamental experiments.

Cathode rays are invisible, but many substances—fortunately glass is of the number—shine with a bright phosphorescent light when placed in the path of the rays. By this means it was early discovered that cathode rays travel in straight lines which always leave the cathode making right angles with the metal surface from which they depart. It is possible, therefore, to make the cathode concave or saucer-shaped and thus bring the rays to a focus at some point in the tube. If cathode rays are thus focussed upon the blades of a very delicate paddle wheel which rotates easily upon an axis, the wheel is set revolving as if struck by a stream of moving matter.

The rays are found to possess an unusual power of penetrating matter impervious to light. They will even traverse a considerable thickness of aluminum. A comparison of the absorbing powers of different materials for cathode rays shows absorption to be roughly proportional to the density of the substance.

There is a field of magnetic force about a beam of these rays and this added to the transfer of electricity along the path gives to the cathode stream the distinguishing marks of an electric current in a wire or a procession of electrically charged bodies. If a magnet be brought near the tube the cathode stream is deflected from its direct course. This deflection by the magnet shows three things: first, cathode rays are not of the nature of light rays, the path of which a magnet is powerless to change. Second, the curved path which the stream follows again shows the stream to possess inertia. Third, the side to which the rays are deflected indicates a stream of negative electricity.

Strongly electrified bodies brought near the tube also deflect the rays. It is possible to determine the speed and the ratio of charge to the mass of the cathode particle, by measurements of the curvature of the path due to the combined magnetic and electrostatic deflections. Speeds as high as one tenth the velocity of light or 100,000 times the speed of a modern rifle bullet have thus been observed. The ratio of charge to mass comes out nearly a thousand times that found for the hydrogen atom by electrolysis. If the charge on the cathode particle is no larger than that on the hydrogen atom, which was called an atom of electricity, then the inertia or mass of these particles is only one one-thousandth part of the mass of hydrogen atoms.

The nature of cathode rays was thus determined, but at this stage it was all important to catch a known number of these missiles and measure the electric charge each carried. As the estimated size of these minute bodies is less than one ten-million-millionths of an inch, direct counting would be both slow and difficult, yet by one of the most ingenious experiments ever performed, Professor J. J. Thomson did it, indirectly.

To bring the essential features of this remarkable experiment before you, I must begin some way off by reminding you of several things you already know. For instance, the quantity of water vapor which a given volume of air at ordinary pressures can hold without depositing it as a mist or rain increases with the temperature. If air enclosed in a vessel is allowed to expand suddenly its temperature falls. If the air were initially saturated with water vapor, after the expansion some of the vapor will go into mist or rain, provided any nuclei are present upon which the excess vapor can condense. In the ordinary fog or shower the dust particles always present in the open air act as nuclei for the formation of drops. Small free charges of electricity or ions serve the same purpose and the negative ions are more effective condensers than the positive, hence they come down first.

In a complicated vessel, which need not be described, Professor Thomson admitted dust-free air saturated with water vapor. This mixture was allowed to expand several times to make sure of freeing it from accidental dust or ions which might be present. The former pressure was then restored and the gas ionized by admitting X-rays through the thin aluminum lid of the gas chamber. The next expansion, chosen sufficient in amount to cause condensation on the negative but not on the positive ions, caused a copious cloud of mist which gradually settled by its own weight to the bottom of the vessel. The top of the cloud as it fell was sharply defined, and its rate of descent could be measured.

Sir George Stokes many years before had calculated the rate of fall of small spherical bodies through air, and one needed to know only the density of a small sphere and its rate of fall to compute its size. The approximate volume of the individual drops could thus be found. The quantity of water in the whole shower could also be easily determined, hence the number of drops, equal to the number of negative ions upon which they might form, could be calculated.

In another way Professor Thomson could measure the total quantity of free negative electricity present in the chamber when the fog was precipitated. He had thus the number of negative ions and the sum of their charges, and therefore the charge each carried.

The charge Professor Thomson found as the result of his brilliant experiment was the atom of electricity over again. After this it was impossible to escape the conclusion that the bodies flying in the cathode stream were masses no greater than the one one-thousandth part of the hydrogen atom. Thus matter, or electricity, or something exists, which measured by inertia is a thousand times smaller than the lightest known atom of matter. Furthermore, the kind of gas in which the cathode discharge took place had no effect upon either the charge or the mass of the particles, which bear no observable earmarks to reveal the kind of matter out of which they come. Whatever their source, they are always the same.

So far as we now know, the cathode particle or negative electron is a minute portion of pure negative electricity, wholly free from matter. An atom of electricity, and nothing more. Its small inertia can be wholly explained to be of the kind electric charges borrow from the ether which surrounds them.

When electrons driven at high speeds down the cathode stream are suddenly stopped by striking a target of dense matter like platinum, the point where the target is struck becomes a source of X-rays. We have already seen that a moving electric charge when brought to rest sends out a pulse of electro-magnetic disturbance in the surrounding ether, and the greater the suddenness with which the motion is arrested, the sharper and more abrupt is the shock to the ether.

In one sense the principal difference between X-rays and the yellow light from a sodium flame is analogous to the difference between the air disturbances caused by an irregular jumble of sharp thin reports of small percussion caps, and the droning of a heavy organ pipe. One is a tangle of single shocks, the other a steady wave motion. Thus regarded, nearly all the remarkable properties of X-rays find a reasonable and easy explanation.

Turning now to the positive terminal of the tube: Under suitable conditions of experiment it is possible to get a stream of particles from it. Named as children are before their natures are in the least understood, these rays were called *canal rays*. Like cathode rays, they consist of flying missiles, but carry positive instead of negative charges. Compared with cathode rays, their speed is very moderate and the ratio of charge to mass is of the same order as that for the lighter atoms in conduction through solutions. This ratio varies somewhat with the kind of gas in the tube. Thus canal rays are probably a stream of material atoms which have lost one or more negative electrons.

All efforts to obtain a charge of positive electricity free from matter —a veritable positive electron—have thus far failed.

The extreme complexity of the material atom is strikingly shown by the light from incandescent gases and vapors. When examined by the spectroscope the single element iron exhibits hundreds of definitely placed bright lines in the visible spectrum alone, which means the iron atom must be capable of vibrating in hundreds of different periods. No single atom need be vibrating in all these ways at the same instant, but if all iron atoms are alike, and we have every reason to believe they are, whether shining on earth or in the stars, then every atom of iron must be capable of swinging or bounding, revolving or shuddering, or doing something in all these ways.

Before the evidence of the spectroscope the older idea of the atom as a simple structureless body falls to the ground. The complexity of a grand piano seems simple in comparison with the iron atom. But spectroscopic evidence does not end here, but indicates *what* it is in the atom which does something and *how* it does it.

Ten years ago Professor Zeeman placed a sodium flame between the poles of a powerful electro-magnet and examined its light by the spectroscope. He observed the most striking and peculiar effects of the magnetic force on the character of the light. The time is too far gone to permit a description of what the effects were, but the light sent out by the flame showed exactly the characteristics which magnetic force would produce, provided the light came from atoms inside which minute electric charges were rapidly revolving. It was even possible to compute the ratio of charge to mass for these revolving mites. The ratio revealed was that previously obtained for the cathode particle.

Hence the mechanism which enables the material atom to emit light may be the same electron we met flying through the vacuum tube, now revolving in an orbit about the atom center as a planet revolves about the sun. Thus the chief difference between the atoms of one chemical element and those of another, may lie in the number and arrangement of electrons in a revolving system.

It had long been known that hints about the internal fabric of the atom would be most effectively sought with the spectroscope, but we have here gained at a single bound the most amazing insight into a most complex system. Here also we meet another of those astonishing previsions of Faraday. He tried Zeeman's experiment over fifty years ago, but was balked in his quest by the inadequacy of the instrumental equipment of his day.

The quite recent discovery of the wholly new and unsuspected property of radio-activity in a group of heavy elements has done much to confirm the views already expressed of the connection between electricity and matter, and much more, for radio-active phenomena suggest for the first time that some kinds of matter are not only unstable, but mutable.

Taking radium as the most highly developed example of its class, we find it, with the help of its numerous progeny, sending out three distinct types of rays, which for convenience of classification have been called α-, β- and γ-rays.

α-rays closely resemble canal rays. They carry positive electric charges and possess a mass or inertia comparable with that of the helium or hydrogen atom.

β-rays appear identical with cathode rays. They consist of negative electrons hurled out at speeds as great as nine tenths the velocity of light.

γ-rays are of the nature of X-rays—a purely ethereal phenomenon. All these rays penetrate matter to varying depths, and absorption varies with density as in cathode rays.

α-, β- and γ-rays all have the power of wrenching electrons free from substances which absorb them. By this power to ionize gases a wholly new method of chemical analysis has sprung up—the method of analyzing by the electroscope. So marvelously delicate is this new radio-analysis that one part of radium in one hundred-million-million parts of uranium can not escape detection. The electrometer test for differentiating the various radio-active substances is the time required for the fresh product gained by chemical manipulation to lose half its ionizing power. This important characteristic of each substance is disparagingly called its *rate of decay.*

By the aid of the new analysis, Rutherford and others have found that radium is slowly disintegrating into radium emanation, which in turn changes into a distinct substance called radium A, and so on by successive steps down the alphabet to radium F, which is possibly a parent of lead. Helium appears also as a by-product of radium disintegration. From radium downward each of the seven substances has a characteristic rate of decay ranging from 1,300 years for radium, to three minutes for radium A. Radium emanation is a gas which liquefies at — 150° C. Some of the later products seem to be solids. Is it not amazing that any of the properties of these six derivative products should be known at all, when never yet has one of them been seen, nor weighed, nor caught for direct examination?

Not only has radium offspring down to the sixth and seventh generation, but it apparently has ancestors as well. It is only a link in a genealogical chain. The probable discovery of radium's immediate parent was published less than a month ago by Boltwood. Uranium is thought a remoter ancestor, possibly a great-grandparent.

Accompanying the atomic disintegration of radio-active substances, large quantities of heat are evolved showing vast stores of energy hitherto unknown inside the atom.

The most reasonable explanation yet offered of the observed radioactive phenomena indicates that the complex system of electrons revolving at enormous speeds within the atom gradually loses energy until the configuration becomes unstable. A sudden readjustment takes place—a kind of internal explosion by which electrons or α particles, or both, are hurled out. The atomic structure thus relieved starts life as a new substance with a lower atomic weight. Later the new substance for a like reason again becomes unstable, another explosion occurs, and an atom of yet another substance is born.

If this interpretation of the evidence be accepted a conclusion of vast importance may be drawn. We have, we can not say going on before our eyes, but we may say in a sense going on under our hands, a slow evolution or transmutation of matter. This conclusion is not accepted as yet without reserve, for it strikes too deep at one of the assumptions of our older knowledge. Material atoms have long been thought of as immutably fixed for all time, but so were animal and plant species before Darwin. The growing evidence for this larger view of matter, though recent, is already too strong to be longer ignored. The burden of proof is gradualy shifting, and to Alice's question, "Why?" comes back the equally pertinent "Why not?" of the March Hare.

To gather a little together: The electron has but a thousandth part of the inertia of the lightest known material atom, and this inertia it doubtless borrows from the kindly ether and does not hold in its own right. Its behavior is that of an atom of negative electricity pure and simple. Its form is spherical and not spheroidal. Its size is probably less than one ten-million-millionths of an inch. When revolving briskly enough in an orbit within the atom it gives us colored light of highest purity. When violently jostling irregularly about it gives us white light. Without it all light would be impossible.

We believe we have found electricity free from matter, but never yet matter free from electricity. Finally comes the suggestion that matter no less than life may be undergoing a slow but endless evolution.

Some of these things and many others have led physicists to suspect that if all electricity were removed from matter nothing would be left, that the material atom is an electrical structure and nothing more.

There are, however, many stubborn questions to which answers must somehow be found before the so-called electron theory of matter can be accepted unreservedly. As it stands it is at once a most brilliant and promising hypothesis, but has not yet reached the full stature of a theory.

Should it hold good, the material atom with its revolving electrons becomes the epitome of the universe. The architecture of the solar system and of the atom, the very great and the very small, reveals the same marvelous plan, the same exquisite workmanship. The conservation of energy becomes an ethereal law and the ether the abiding place of the universal store of energy.

To end as we began, we have matter and electricity which some day may be one, and ether and energy. Of these we hope some time to build in theory a reasonable world to match the one we now so little understand.

When all the interrelations among matter, ether, electricity are separated out and quantitatively expressed, we believe our work will be complete.

Such, then, is the confession of faith, the very far-distant hope of the modern physicist.

THE RESPIRATION OF AN INLAND LAKE[1]

BY PROFESSOR E. A. BIRGE

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AN inland lake has often been compared to a living being, and this has always seemed to me one of the happiest of the attempts to find resemblances between animate and inanimate objects. Unlike many such comparisons, which turn on a single point of resemblance and whose fitness disappears as soon as the objects are viewed from a different position, the appropriateness of this increases rather than diminishes as our knowledge both of lakes and of living beings is enlarged.

The lake, like the organism, has its birth and its periods of growth, maturity, old age and death; and this fact is an obvious one, for of all the larger features of the landscape, the lake is the youngest and the most temporary. Its birth lies in the recent past, and in no very long space of time its existence must come to an end. In any lake district, lakes may be found in all stages of maturity and decay, and many dead lakes will be seen—places where lakes once existed which are now extinct. Lakes show not only the cycle of individual existence, but also the rhythm of seasonal activity. The activity of the lake in summer, both physical and vital, contrasts sharply with its torpidity in winter. And the lake resembles the organism not only in its annual recurrence of activity. The comparison may be pushed farther and extended to the minor fluctuations of the vigor of vital manifestations which characterize lake and organism alike.

In all these points, and in many others, the lake resembles a living being; but in no respect does it resemble an organism more closely than in the topic on which I am going to speak to you, namely, its respiration. In this comparison, the resemblance is rather in processes and operations than in form. The lake is morphologically a very simple creature, resembling rather a gigantic amœba than a more highly organized being. Perhaps it would be better to compare the lake, for the purpose of this subject, not with the organism as a whole, but with the special respiratory substance of the animal—the blood.

Like the blood of the higher animals, the lake consists of an unorganized fluid—the plasma of the blood and the water of the lake—and of numerous organized and actively living parts—cells in the case

[1] Address of the President at the Thirty-sixth Annual Meeting of the American Fisheries Society, Erie, Pa., July 23–25, 1907.

of the blood, and the plants and animals in the lake. As is the case in the animal, the respiratory gases are absorbed and transmitted to the living structures by means of the unorganized fluid. It is my purpose to trace in outline the history of these processes and their result upon the activity of the lake.

The respiration of the lake, like that of the higher animal, may be divided into external and internal respiration. By the former we understand the adsorption of certain gases from the air and the return of other gases to it, as well as the processes by which this exchange is effected. We include in it also the methods by which the gases are distributed in the lake and conveyed to and from the surface of the water, which takes them from the atmosphere and gives them back to it. By internal respiration we mean the gaseous exchanges which take place in the lake itself, between its various organisms and the water surrounding them. With these exchanges come the chemical processes by which the character of the gases is altered or new gases manufactured, in the course of the vital activities of the inhabitants of the lake.

The external respiration of the lake closely resembles that of the organism. The lake absorbs oxygen, carbon dioxide and nitrogen from the atmosphere, and returns to it nitrogen, carbon dioxide and sometimes other gases. The nitrogen absorbed by the lake, like that taken in by an animal, has very little or nothing to do with the vital processes. In autumn, as the lake cools, larger amounts of nitrogen are absorbed, according to the general law of absorption of gases. As the lake warms during the summer season, the capacity for holding gases in absorption becomes smaller and some of the nitrogen is lost. This process is a purely physical one and has apparently no influence on the life of any of the organisms whose home is in the water.

The relation of the oxygen to life is, however, far different, and the processes of external respiration are of prime importance to the living beings of the lake. Speaking roughly, and in terms of our comparison, we may say that an inland lake is an organism which takes one full inspiration in the fall, and another, less complete, in the early spring; that during the winter it does not breathe at all and during the summer has only a very shallow and imperfect respiration. As the lake cools in the fall the temperature becomes uniform from top to bottom at a date which will vary from late September to late November or early December, according to the area and the depth of the lake and the consequent temperature of the bottom water, the volume of water to be cooled, and the vigor of the cooling processes. When the temperature has thus become uniform, the water of the lake is readily moved throughout its entire depth by the wind. It is turned over and all parts of it are brought into contact with the atmosphere. As a result, inland lakes, even those whose depth is two hundred feet or more, become almost, or quite, saturated with oxygen at a temperature but little above the freezing point. This quantity amounts to about 10 c.c. per liter, or about 1 per cent. by volume; nearly twice as much as the water will hold at the highest summer temperature. In this condition as regards oxygen the lake goes into winter quarters, becomes covered with a sheet of ice in our latitudes, and is, therefore, shut off until spring from all further direct connection with the atmosphere. During this period the stock of oxygen is used up to some extent, especially in the water adjacent to the bottom. But as the vital processes of both plants and animals, and also those connected with decay, go on slowly at the low temperature of the water in winter, the amount of oxygen thus consumed is comparatively small, and most lakes contain an abundance for all forms of life at all depths, except perhaps in the strata very close to the bottom. This statement, though generally true, will not hold universally. In some ponds which are shallow and contain a large amount both of living organisms and of decomposing matter, the oxygen beneath the ice may become wholly used up. We all know of lakes where, if a hole is cut through the ice in late winter, the fish will crowd to it for air so eagerly and in such numbers as to be forced out on the ice. There are on record cases where an unusual exhaustion of the oxygen below the ice of a lake has caused the death of most of the fish. Such cases, however, are not common, and in the great majority of lakes the consumption of oxygen in winter does not go far enough to affect unfavorably their living inhabitants.

Associated with this partial exhaustion of oxygen, there is an increase during winter of the amount of carbon dioxide—the main gaseous product of respiration. This is not present in any observable quantity in the lake at the time of freezing, but it increases during the winter and the quantity at the bottom may become very considerable. The amount will be, in general, proportional to the amount of oxygen used up. In the spring, when the ice has melted, the water of the lake is once more uniform in temperature. It is put into motion once more by the wind and all parts of the water are brought into contact with the air. The carbon dioxide, which has been accumulating during the winter, is discharged or used by plants and the lake again becomes nearly saturated with oxygen. But, as the temperature in spring is higher than in the autumn, the amount of oxygen taken in is less, and since the temperature of the water continues to rise, the stock of oxygen is being diminished from this cause quite independently of any use made of the gas by the organisms of the lake.

The period of full oxygen saturation in the spring is a brief one in our climate. The season advances very rapidly and the surface water soon acquires a higher temperature than that at the bottom. This warmed water is, of course, lighter than the cooler water below and tends to float upon it. The difference in density thus caused makes it increasingly difficult for the wind to create and maintain a complete circulation of the water. For a time the action of the wind may continue to mix each successive stratum of water with that below it, the mixture extending to the bottom of the lake. But this action is a very different thing from a complete overturning of the water; and while it results in raising the temperature of the lower water, it does not carry freely oxygen to the bottom. Thus, when the surface becomes decidedly warmer than the water below it, the bottom water, though it continues to warm, is withdrawn from direct contact with the air and is therefore at a disadvantage in the matter of gaining a new supply of oxygen.

As the season advances this stratification of water dependent on temperature becomes accentuated, and the lake becomes separated into two parts: an upper warm stratum of nearly uniform temperature, beneath which lies the cold water consisting of a transition layer—the *thermocline*—in which the temperature is rapidly falling, and below this the mass of the cold water whose temperature ordinarily falls rather slowly with the depth until the bottom of the lake is reached. The thickness of the upper layer varies with the size of the lake, from ten to twelve feet to thirty or forty feet. It is present as a definite and permanent layer at a date varying with the area of the lake from late April to the middle of July. It increases in thickness after the cooling of the lake begins, but does not change much before that process commences.

This upper layer is subject to the direct action of the wind, is kept in circulation, and may be saturated with oxygen, or nearly so, but the only new supply of oxygen which the lower water can gain must come to it indirectly from the upper stratum. This condition of permanent stratification of the water comes on at the time when the life of the lake and its consequent need of oxygen are rising to the maximum, with the increasing warmth of summer and the development of life. The consumption of oxygen for the purposes of decomposition is also at a maximum. The separation of the lower water from the atmosphere in summer by a thick layer of warm water is therefore a much more serious thing than the separation of the water from the air in winter by ice. In winter the demand for oxygen is at a minimum and the stock contained in the water is at a maximum. In summer both of these conditions are exactly reversed. It is therefore necessary for us to inquire as to the means which the lake has for absorbing oxygen from the air and its means of transporting the gas from the surface to the place where it is to be used, and to note the efficiency of these processes as compared with the call for oxygen in the summer life of the lake.

The absorption and distribution of oxygen constitute one of the fundamental problems of life for any large and active organism. The difficulty of solving the problem is increased by the fact that no large reserve stock of oxygen can be maintained. In the case of a human being there may a food supply in the tissues sufficient to sustain life for weeks, even though no new supply is taken in. There is water enough in the body to maintain life for days; but if the supply of oxygen is shut off, life can be continued only for a very few minutes on the stock of oxygen contained in the body. So narrow is the space between abundance of oxygen and death from oxygen starvation. In a cold-blooded animal—with which the lake ought to be compared—processes of respiration are slower, but the relative situation is not materially different. The result of these conditions is that in any large animal enormous surfaces must be provided for the absorption of oxygen and there must be a very perfect mechanism for its distribution. Such respiratory systems exist in a great variety of forms, many of which are extremely complex and efficient. In the case of man the absorbing surface of the lungs is said to amount to about two thousand square feet—an area as great as that of floor, ceiling and walls of a room 20 feet square and 15 feet high. The necessity for arrangements for a large absorbing surface increases with the size of the animal, since in a large organism the area of the general surface is far smaller in proportion to its mass than in a small organism of the same shape. In a lake, whose size is enormous as compared with that of any living being, the absorbing surface is very small as compared with its mass; being only the upper surface of the water. The lake is, therefore, at a great disadvantage in the matter of absorbing oxygen as compared with the animal. Still further, all higher animals, both cold-blooded and warm-blooded, contain in their blood some chemical substance which has a special affinity for oxygen and which can rapidly pick up large quantities of it. Such a substance is wholly lacking in the water of the lake, whose respiratory power is correspondingly small as regards both the rapidity with which oxygen can be taken up and the amount which can be absorbed. It is indeed true that water will absorb, according to the general laws of the absorption of gases, about twice as much oxygen as nitrogen under similar conditions. This fact allows the lake to take in a larger stock of oxygen than would otherwise be possible, and that part of the atmosphere which is dissolved in the lake contains about one third oxygen instead of one fifth, as is the case outside. But even this amount is very little in comparison with the enormous volumes which a substance like hemoglobin can take up. It is also true that the mass of the water of the lake, in comparison with the mass of the organisms which draw their oxygen from it, is relatively far greater than the mass of the blood with reference to that of the cells which take their oxygen from it. Yet is it none the less true that the supply of oxygen in most lakes is very small as compared with that of an animal, and the mechanism for renewing it is always very inefficient as compared with the demand for the gas.

The disadvantage of the lake in the matter of respiration appears still more clearly when we consider the means of transporting the oxygen from the region where it is absorbed—the surface—to the deeper parts of the lake, where much of it is to be used. The animal shows a complex and very efficient mechanism for the circulation of the blood; an apparatus whose complexity and efficiency are in large measure determined by the necessity for a rapid distribution of the oxygen and a rapid disposal of the gaseous wastes of the body. In the lake the means of transport are three: diffusion, by which the gas is slowly passed from point to point in the water independently of currents; currents produced by the wind; and convection currents, produced by the cooling of the surface water to a temperature below that of the water beneath.

Diffusion is a process which operates rapidly when the distances are minute, but whose efficiency decreases greatly as the distances increase. In our lungs, or the gills of a fish, for instance, where the distance between blood and air is measured in thousandths of an inch, the process of diffusion goes on with great rapidity. But where, as in the lake, the distances are measured by inches or by feet, or even by scores of feet, the process is practically worthless for the processes of distribution. By diffusion alone oxygen would penetrate the lake only to the depth of a very few feet in a whole season. While diffusion, therefore, plays an active and important part in the exchange of gases between the individual plant and animal and the water immediately surrounding it, it has little or nothing to do with the general circulation of gases within the lake.

During the fall, when the lake is cooling, convection currents aid materially in carrying oxygen down to considerable depths. The surface water, saturated with oxygen, cools, becomes heavier, and sinks, carrying the gas with it. The same process takes place at night in summer, but ordinarily to very small depths. In general, we may say that during early and mid-summer, before the period of general cooling begins, these processes do not extend to greater depths than ten or fifteen feet. At the season, therefore, when vital processes are most active and the need for oxygen is greatest, convection currents afford a minimum of assistance in distributing it. The main reliance, therefore, for the distribution of oxygen is in the third factor, the wind. This, as already said, is very efficient when the lake is uniform in temperature; but during the spring, as the lake warms, it becomes increasingly ineffective, and during the summer its action is confined to the upper warmed layer of the lake, and the lower, cooler, water is wholly shut off from the direct influence of the wind currents.

These facts show that an inland lake has an extremely inefficient apparatus for absorbing and distributing oxygen, and the net result is that in many lakes the amount and character of the higher life which the lake will support is conditioned by the amount of oxygen which the lake contains rather than by the amount of food which it can produce. The oxygen in the lower and cooler water of the lakes can not be renewed between spring and fall. This amount would be indeed ample to sustain a large amount of animal life in full activity. But its use can not be confined to the necessities of ordinary life. The processes of decomposition draw upon it much more heavily than does the animal or the ordinary vegetable life. All the plants and animals of the upper water, which die and sink into the deeper strata, the leaves blown into the lake, and the material washed in from the shore, decompose in the cooler water and in the process of decomposition use up a great amount of oxygen. This depletion of the stock of oxygen goes on with a rapidity which varies with the amount of decomposing matter dropping into the lower water, which to some extent regulates the rapidity of decomposition, and, with the depth of the water, on which depends the quantity of oxygen contained in it. Each of these factors may and does differ in different lakes, but the result is that in a very large proportion of our inland lakes the bottom water loses its stock of oxygen comparatively early in the season and becomes uninhabitable for higher animals. This fact excludes from our lakes a good many kinds of animals which they might otherwise support, and very greatly limits the quantity of the higher life which the lake is able to maintain. A lake which loses its bottom oxygen, for example, can not support a fish such as the lake trout, which must retire to the deeper and cooler water during the summer. To causes such as this may probably be attributed a considerable number of our failures in the planting of fish in our inland lakes. From causes such as these, the whole of the lower water, containing half, or more, of the volume of the lake, may become uninhabitable during the season when life is most abundant; and the quantity of life which the lake supports may be correspondingly limited.

Still further, since the rapidity with which the oxygen is exhausted depends on the amount of material which is deposited in the lower water, those lakes whose upper water contains the greatest quantity of vegetable life and which can therefore support the greatest amount of animal life, use up the oxygen of the lower water most rapidly. It looks, therefore, as if we were in a somewhat unfavorable situation as regards the possibilities of higher life in the lower water of inland lakes. Those lakes whose food supply is such that they are capable of supporting large quantities of animal life—I may say for our purposes, large numbers of fish—are likely from that very fact to exhaust the stock of oxygen in the lower water, which thus becomes uninhabitable; while those lakes whose lower water is fully habitable are likely to be so poor in organic life that they can support only a limited number of fish. It may be that further study will show that this relation is not so unfavorable as it now appears, but at present we must face the probability that it exists.

A noteworthy exception to this statement should be made in the case of very deep lakes—lakes two hundred or more feet in depth—in which the quantity of the lower water is so great and the consequent amount of dissolved oxygen is so considerable that no ordinary amount of decomposing material can exhaust it or materially reduce it. This is the case, for example, with Green Lake (237 feet in depth) in Wisconsin, and the same statement would doubtless hold for the deep lakes of New York and similar bodies of water. Such lakes may support an abundant population of fish both in the warmer and in the cooler water. If they do not do so, the fault does not lie with the oxygen supply.

Thus we see that if we desire to determine the capacity of a lake for the development of higher life, we must consider not only its capacity for food production, but also its respiratory conditions. It may be that an imperfect respiratory mechanism renders a very large share of the bottom of the lake wholly uninhabitable for animal life during the warmer part of the year; that while, for instance, mud-living insect larvæ may be found in the mud around the lake to a depth of twenty or thirty feet, they are excluded by the absence of oxygen from the entire bottom of the lake beyond this depth, an area of perhaps many square miles. The supply of food which the lake offers to the higher animals may thus be greatly limited by the lack of oxygen. It may be true also that the greater part of the volume of the water of the lake is uninhabitable for similar reasons, and that a lake whose surface appearance would indicate that it is capable of supporting enormous quantities of fish may be very considerably restricted in this respect by its respiratory capacity. Each lake should be studied as to both food and oxygen if an intelligent economic use is to be made of its waters; and when this is done, the possibilities of use will often be found to depend on the respiratory mechanism.

I have said nothing on another side of the methods of absorbing and transporting gases in a lake. The same processes which take oxygen from the surface bring waste gases to it and they are as efficient, or as inefficient, in the latter operation as in the former. Processes of absorption and transportation have much to do with the story of the complex relations of carbon dioxide gas in the lake. These matters, however, can better be spoken of under internal respiration. I need only say here that the accumulation of waste gases in the lower water does not seem to affect life unfavorably if there is plenty of oxygen present also. Respiratory inefficiency limits life in a lake because of lack of oxygen rather than because it allows poisonous gases to collect in large quantities.

The subject of internal respiration deals with the changes of gases within the lake itself and with the manufacture of gases by the organisms which inhabit it. No branch of physiology is more intricate and none less understood than is that of internal respiration. This is true also of the internal respiration of the lake. The gaseous exchanges and the manufacturing operations in the interior of a lake are far more complex than those of any animal. From the water living beings are drawing supplies of gas, each after its kind, and to the water each is contributing gases differing in amount and composition. Animals are withdrawing oxygen from the water and giving carbon dioxide to it. Algæ are repeating this process by night and exactly reversing it by day. Fungi and bacteria are using oxygen in the course of their internal vital activities; they are employing far larger quantities in the fermentative processes which they maintain. The innumerable chemical changes included in decomposition and fermentation, going on under all sorts of conditions, involving numerous kinds of materials, and operated by various organisms, are adding to the water gases of different kinds and in varying proportions. The upper water, the lower water and the mud present very dissimilar fields of work to the organisms which inhabit them. It is, therefore, impossible even to attempt a picture of the internal respiration, with its countless operations, each adding to or subtracting from the sum of gases in the lake; in an intricate network of processes, consecutive, correlative and antagonistic; connected by relations which cross and interlock at a thousand points. I shall speak of only a few detached topics.

I have said that the oxygen of the lake is absorbed from the air. This is true so far as the main stock of oxygen is concerned; but a lake has a second source of oxygen which is always considerable and which in certain places and relations may become important. The green plants which inhabit the lake are able to take up carbon dioxide from the water, and under the influence of light they can use it in the manufacture of starch, setting free oxygen in the process. In lakes which contain an abundance of algæ, considerable quantities of oxygen may arise from this source and this manufactured oxygen may play an important part in the vital history of the lake.

Consider the effect of the addition of this power of the algæ to the numerous factors which are affecting the supply of oxygen in the upper water of the lake in summer. If the oxygen of this region is studied, it rarely happens that the quantity found is the amount which would be theoretically expected, according to the laws of the absorption of gases by water at different temperatures. It is sometimes largely in excess of the theoretical amount, and sometimes is considerably deficient. The fact is that the amount of oxygen in the upper water of the lake is the resultant of very numerous and variable forces. The lake may or may not be absorbing oxygen from the air. If saturated, it will give off oxygen to the air as the water warms, or will take it in as it cools. Both of these processes go on somewhat slowly, and the oxygen is not given off or absorbed as rapidly as the water warms or cools. Into the water the green plants are discharging oxygen during the hours when the light is sufficiently strong; from the water both plants and animals are taking oxygen to assist their vital operations; and the process of decomposition is aiding to exhaust the stock of oxygen. Thus the amount present at any given moment will depend on the relative value of these forces; some of them positive; others negative; and all varying not only from day to day, but from hour to hour. Nor do these factors exhaust the list. The wind has something to do here; during a calm period the oxygen content of the upper water may differ from that of a stormy period. The vital condition of the successive crops of algæ, as they come and go, may determine for the time the predominance of the manufacture of starch, with accompanying liberation of oxygen, or decomposition, with partial exhaustion of oxygen. Thus the ability of the green plant to set free oxygen into the upper water may be of great value in maintaining the supply of the lake.

This power may be far more important in the lower water. If the transparency of the water and the thickness of the warm layer are such that a good deal of light can penetrate to the colder water, algæ will be able to manufacture starch in the upper part of this stratum. Thus in the region which is practically cut off from access to the atmosphere, large amounts of oxygen may be set free. There may be enough not only to serve the ordinary needs of the stratum, but the water may be saturated or even oversaturated with the gas. To illustrate this point I give a diagram (Fig. 1) showing the vertical distribution of oxygen in Elkhart Lake, Wisconsin. This figure shows clearly the position and amount of the manufactured oxygen, and the addition which it makes to the thickness of that part of the lake that has abundance of oxygen. Lakes whose habitable portion would otherwise be only twelve to twenty feet in thickness may have this depth nearly or quite doubled by the presence of the manufactured oxygen. The plants in this undisturbed cooler water find a peculiarly favorable situation for growth. They obtain for their food the products of decomposition, which is taking place rapidly in the lower water; and not infrequently a far larger amount of organic life may be found in these strata than in any other portion of the lake. This process is necessarily limited

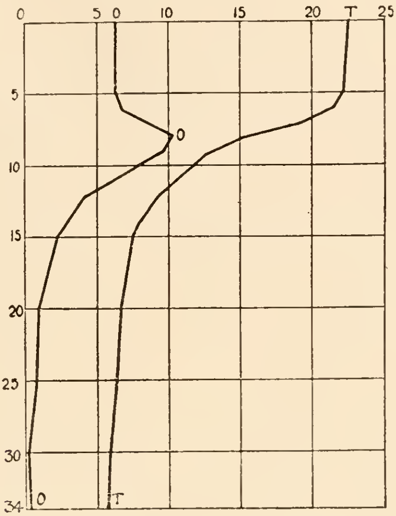

FIG. 1. ELKHART LAKE, Aug. 23, 1905. The vertical spaces indicate the depth in meters. The horizontal spaces indicate cubic centimeters of oxygen per liter (parts per thousand of volume), as shown by the line *O---O*. They also indicate the temperature in centigrade degrees, as shown by the line *T---T*. The upper, warm layer of water is about 6 m. thick; the thermocline extends from 6 m. to about 10 m. The presence of the manufactured oxygen is very plainly seen in the space between 5 m. and 12 m.; the amount of oxygen rising to a maximum of over 10 c.c. per liter at the depth of 8 m. The relation of this gas to the temperature of the water and the consequent stratification is clearly shown.

to lakes whose upper warm layer is thin, and is confined to the upper part of the cold water, since only there can the light have sufficient intensity to carry on the operation. But even thus restricted, it is of great value to some lakes.

I have said little hitherto of the carbon dioxide—a gas whose importance is quite equal to that of oxygen—and now can only sketch a part of its complex story. This gas plays many rôles in the respiration of the lake. It is at once the waste product of the tissue activity of plant and animal, the product or by-product of decomposition, and the indispensable food of green plants. The lake may obtain the gas from the air, and to some extent does so. Carbon dioxide exists in the atmosphere in very small amount—about four parts in 10,000. Minute as this quantity is, the land plants are able to secure from it ample supplies of carbon. The movement of the air is so free and such enormous quantities pass over the surface of the plants, that they readily pick up the gas in large amounts. But the situation of the algæ and other plants of the lake is very different, as they must secure their carbon dioxide through the intermedium of the water. This readily absorbs large quantities of the gas. But the percentage existing in the air is so small, the absorbing surface of the lake is so restricted, and the means of transport are so poor that the lake is quite unable to take from the air enough carbon dioxide to maintain a vigorous growth of plants. The lake is forced to depend on its own resources to a large degree for this plant food. Fortunately, these resources are considerable. Great amounts of carbon dioxide are manufactured in the lake and these may be utilized as food by the green plants. Thus there is kept up in the lake a sort of internal circulation of carbon dioxide; the stock of the circulating medium being increased and replenished by additions from outside. The activities of animals and the processes of decomposition liberate the gas, which is taken up and manufactured by the plants into organic substances; and these in turn serve as food and as material for new decomposition; while from the air the water may be absorbing new supplies of carbon dioxide to make good the losses of this process. Thus under normal conditions, the lake would return little or no carbon dioxide to the atmosphere, but would utilize within itself all that it manufactured or absorbed, at least until the plant life became so abundant as to be limited by other causes than that of food supply.

If this were all, the story would be quite simple and quite to the advantage of the lake. But it is by no means all the story; on the other hand, so far from being forced to solve problems associated with an oversupply of carbon dioxide, the lake has to encounter many difficulties in securing an adequate supply of that gas, and is able to meet them only very partially and imperfectly. Since the plants are able to utilize carbon dioxide in the manufacture of starch only during the hours of sunlight, considerable quantities may escape into the atmosphere during the night. But this is not the only disadvantage as regards the supply of carbon dioxide, with which the plants of the upper water have to contend. By no means all, or even the greater part of the organic matter which they manufacture decomposes in the upper, warmer stratum of the lake. As the plants and animals die, they sink into the lower and cooler water before any great part of the decomposition has been completed. The carbon dioxide which is there produced is discharged into this bottom water. It can not be used there by plants on account of lack of light. The same imperfections of transportation which prevent the access of oxygen to the cooler water in summer make it impossible to transport the carbon dioxide produced there to the upper stratum, where it can be utilized. In certain lakes, indeed, a small portion of this gas may be used in the cooler water, as I indicated above, but, in general, the upper water, as a result of this process, is growing poorer during the summer in the materials on which plants feed, both gaseous and other. These are for the time locked up in the lower water and so withdrawn from the circulation of life. In the autumn, as the lake cools and the thickness of the circulating stratum increases, these matters become available so far as they lie in the upper part of the cooler water, and when the lake has become uniform in temperature to the bottom, and the water is turned over by wind, the whole of this accumulated stock is available for the purposes of plant growth. This may be one of the reasons for the abundant growth of algæ, which takes place in the autumn. But while the non-gaseous products of decomposition may be wholly utilized in the lake, the carbon dioxide is hardly likely to find full use. When it once becomes distributed through the water and new portions of the water are being continually exposed to the air, considerable quantities must escape during the hours when plants are unable to avail themselves of it.

Thus the rudimentary character of the circulatory apparatus of the lake forms an insuperable obstacle to the best utilization of the food supply. It is therefore easy to see why life is relatively so abundant in large and shallow lakes, in which the circulating methods have a maximum efficiency. The fact that these lakes are shallow permits a larger growth of life, since not only is the water available but plants in large quantities may grow from the bottom. But of even more importance than this relation is the fact that since the entire mass of water is kept in circulation by the wind, all the products of decomposition are immediately available for use and the life cycles of the plants may go on as rapidly as their rhythm of growth will permit. The carbon dioxide and other products of decomposition, instead of being locked up in the deeper water and set free only during that season which is least favorable for growth, are utilized immediately and are employed over and over again through the warmer season as the cycles of life and death of the individual plants recur. It is plain that lakes whose margin is wide and shallow, though the middle may be deep, must stand next to the shallow lake in efficiency of means of transportation. Much growth takes place in the shallow waters, much decomposition goes on there, and relatively little of the organic matter sinks into the deep water, to be withdrawn from circulation. Least favorably situated is the deep and steep-sided lake, whose cold depths are continually swallowing almost all of the products of the summer's growth, and give them back for use, only late in the autumn when the season for active life is passing away.

Some lakes may find aid from another source in the task of securing carbon dioxide. Most natural waters contain a certain amount of calcium and magnesium salts in solution, and, for the greater part, these exist in the form of bicarbonates. Lakes whose water is hard contain a considerable amount of these bicarbonates and soft-water lakes have little or none. In hard-water lakes it is found that during the growing season, when algæ are active, the upper water contains no free carbon dioxide, but is, on the contrary, alkaline, when tested with phenophthalein as an indicator. This alkalinity comes from the fact that one molecule of carbon dioxide has been withdrawn from part of the bicarbonates, converting them into carbonates. It appears that the algæ are able to effect this reduction and that they can obtain their supply of carbon from the carbon dioxide of the bicarbonates dissolved in the water. This fact introduces a wholly new feature into the story of the food supply of the plants. It provides a chemical carrier for the carbon dioxide which may carry this gas somewhat as the hemoglobin carries oxygen in the blood. All carbon dioxide set free in this alkaline water as the result of decomposition or other processes, will be taken up immediately by the carbonates. Thus if plants are not at hand to utilize the carbon dioxide at once, it is not lost but kept until it is needed. So in the night, the lake is able to retain all the carbon dioxide set free and which the plants do not use at that time.

Such alkaline water has also a great advantage in absorbing carbon dioxide from the air. It presents for absorption, not merely the relatively weak and slow powers of the water for dissolving the gas, but the eager and vigorous powers of chemical affinity. And until these alkaline carbonates are saturated, no free carbon dioxide will appear in the water to diminish the rapidity of absorption from the air. Thus hard-water lakes have an advantage over soft-water lakes in the matter of securing plant food, and in fact the population of soft-water lakes is smaller than that of lakes of the other type.

It is worth while to devote a few words to gaseous products of decomposition other than carbon dioxide. So long as the bottom water contains an abundance of oxygen no other gas than carbon dioxide is produced in appreciable quantities. But as the oxygen becomes greatly reduced or wholly disappears, decomposition continues in new forms and under these conditions of anaerobic fermentation other gases may be developed in considerable amounts. It is apparently true that carbon monoxide may be present in the lower water of lakes in appreciable quantity, and it is certain that marsh gas is developed in large volumes in lakes where the amount of fermentable material is large and where the oxygen disappears from the lower water early in the season. These gases first appear near the bottom, where decomposition is going on most actively and where the oxygen first disappears. In many lakes they are found only in small quantities and close to the bottom, but in proportion as the amount of decomposable matter increases, they are found at considerable distances from the bottom, and in certain lakes all of the water below the thermocline may contain marsh gas in appreciable quantities, often becoming very great as the bottom is approached. These gases do not seem to have any very definite unfavorable effect on the life of the lake. Diffusion is so slow that they do not reach the upper water and experiments indicate that their presence in the lower water adds little, or nothing, to the unfavorable conditions brought about by the absence of oxygen.

It should be noted that these processes involve a loss of material for plant food. Carbon dioxide, produced by aerobic decomposition, is available for plant food in the lake, or, if not there, then elsewhere as part of the general stock of that gas in the atmosphere. But marsh gas has no such relation to plants and all substances converted into it are lost to the cycle of life. Its production means just so much reduction of the food supply of the lake. The same may be said of the carbonized, peat-like substances produced from the partial decomposition of plants under water. So long as these remain under water, they are practically withdrawn from the food supply. Against all these influences which tend to diminish the stock of food for its inhabitants, the lake is contending, but with imperfect means and only partial success.

I have thus hastily and imperfectly sketched the respiration of an inland lake, not because the story is known with any fullness or completeness, but partly because our present knowledge, imperfect though it is, shows that the subject is one of great scientific interest; partly also because many practical hints regarding the utilization of lakes in fish culture can come from our knowledge of respiratory conditions. We are accustomed to think of the food-producing capacity of the lake as the factor which determines the kind and amount of the crop of fish which it can produce. It is a somewhat new thought to me, and I have no doubt that it is equally new to many of you, that the respiratory capacity of the lake may have even greater influence in this matter than has the capacity for the production of food. Yet it is plain that such is the case and that a knowledge of the respiratory conditions of the lakes in which our fish are to be planted is necessary if the best results are to be reached.

THE UTILIZATION OF AUXILIARY ENTOMOPHAGOUS INSECTS IN THE STRUGGLE AGAINST INSECTS INJURIOUS TO AGRICULTURE[1]

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I. The Rôle of Entomophagous Insects in Nature

If phytophagous insects could develop and multiply without hindrance in proportion to their natural reproductive power, in a short time they would cause all species of terrestrial vegetation to disappear. The multiplication of these destructive forms is very fortunately kept within limits compatible with the existence of plants by the presence of other insects, predatory or parasitic, which places a check on their propagation.

The capacity for prolification of entomophagous insects is itself very considerable: their eggs may often be counted by hundreds or even by thousands; moreover, as several of the species of parasites often attack a single species of plant-feeding insect, it is certain that the latter would in its turn become very rapidly annihilated if the parasites were not themselves held in check by hyperparasites, and if they were not repressed in their spread by all the obstacles that render their struggle for existence more difficult than can be imagined.

The rôle of entomophagous insects is of the first importance, whether from the point of view of the economy of nature or from the point of view of utility to man.

Some, like the Carabidæ and Coccinellidæ, are predatory. They destroy for food the insects which they attack, and the benefit derived from their action is immediate.

The others, which are represented both by the hymenopterous and dipterous parasites, lay their eggs in the interior of developing insects, or in their near neighborhood, and the larvæ which hatch from these eggs nourish themselves at the expense of their hosts, accomplishing their death at a more or less advanced stage of their evolution. In this case the benefit brought about is sometimes immediate, as in certain species of minute Hymenoptera (*Teleas, Tetrastichus,* etc.) which lay their eggs in the interior of eggs of other insects and

[1] Translated from "The Annals of the National Agronomical Institute" (Superior School of Agriculture), Second Series, Vol. VI, Part II, Paris, 1907, pp. 281–354.

complete their development within the eggs. The phytophagous insect is then killed within the egg, and the plant thus completely escapes its depredations.

Much more frequently it does not immediately stop the growth of its host; it introduces its egg into the phytophagous insect and in the more or less advanced stages of its development, either during the embryonic period (*Encyrtus fuscicollis,* divers Platygasters), or frequently during the larval or nymphal period (Ichneumonids, Braconids, etc.). The phytophagous insect which carries in its interior the larva of the parasite, continues to grow and to feed upon vegetation, and is killed by the parasitic insect only when the latter has reached its full development, and when the host has done all the damage it is capable of doing during its existence. The benefit accomplished by the parasite is manifest only in the following generation, and consists in the suppression of the descendants that would have been mothered by the phytophagous larvæ, if they had been able to develop until their transformation into adult insects.

Whether they belong to one or another of these catagories, the predatory and parasitic insects play a regulating rôle that is useful and remarkable. When, on account of cultural conditions or climatic circumstances or other influences, the phytophagous species tends to increase beyond the average, it thus furnishes conditions eminently favorable to the multiplication of the parasitic species, and that in its turn causes the phytophagous form to decrease.

In a very interesting, but insufficiently known work, Bellevoye and Laurent (1897) have shown that it is not necessary that the parasite should have a greater fecundity than the phytophagous species in order to bring the latter back to its normal condition when it has exceeded it. As paradoxical as is this assertion, with a fecundity simply equal and even inferior, it may rapidly reach the point of annihilation, if other factors and other conditions do not interfere to interrupt this action. All other things being equal, nothing prevents the development of the parasites, so that by their work a greater and greater quantity of the plant-feeding species are destroyed each year. In order to state this fact precisely let us, with the authors just cited, take as simple an example as possible, that of an invasion of the caterpillars of *Bombyx.* Suppose that at a given period the proportion of parasitized caterpillars is one fourth, and that the parasites have placed a single egg in each caterpillar. Of 8 chrysalids, 6 will give out *Bombyx* and 2, parasites. We will suppose that of the 6 moths there are 3 males and 3 females; and of the 2 parasites, 1 male and 1 female. Let us suppose that the fecundity of the parasitic species is equal to that of the host species, and that the number of eggs laid by a female of each of the two species is 100.

We will have for the first year 300 caterpillars, of which 100 will be parasitized. That will give, as eventually issuing, 200 moths (100 females) and 100 parasites (50 females).

The second year there will be 100 times 100 = 10,000 caterpillars of which 50 times 100 = 5,000 will be parasitized. That will be 5,000 issuing moths and 5,000 issuing parasites with 2,500 females of each species.

The third year the number of caterpillars will be 2,500 times 100 = 250,000 and all these will be attacked by parasites so that there will be no moths issuing.

This theoretical example shows very well how an injurious species, after having increased in threatening progression during several years, immediately after having reached its maximum can suddenly disappear in a short time under the influences of the parasite. The diminution of food also contributes to limit the propagation of the plant-feeding species, and may hasten the inevitable triumph of the useful species. Every one who is interested in agricultural entomology knows that incidents like this are frequently observed in nature. When an insect has been very injurious for two or three years, and has multiplied to the point of taking the proportions of a veritable plague, it disappears, usually in a sudden manner at the moment when the alarm which it has provoked has reached its highest degree. Experience has shown that it is almost always to the work of parasites that these rapid retrocessions of injurious species must be attributed.[2]

The damage of the Hyponomeutas to fruit trees is almost always stopped at the end of two or three years by Tachinids, or other parasites. The same thing occurs with the Bombycids which devastate coniferous forests.

A remarkable example of the same phenomena is shown with the Cecidomyiids of cereal plants.

After the destruction caused in Vendee and in Poitou by the Hessian fly and the oat midge, in 1895, these insects disappeared almost completely, and the farmers had no further cause to complain of their presence.

Now I ascertained that an enormous majority of the pupæ which should have been in the grain at the end of 1894, or the beginning of 1895, were parasitized. So much so that it was difficult for me to find specimens with which to carry on certain studies in which I was engaged at that time. Having collected in March, 1895, in the suburbs of Poitiers, some stubble from the harvest of 1894, remaining through the winter and containing an enormous quantity of the pupæ of the flies, I obtained in the jars in which I had this stubble enclosed, only a

[2] Aside from parasitic insects, bacterial or fungous epidemics may intervene in a similar manner, but the consideration of these does not fall within the province of this article.

cloud of parasites which came out during the months of April and May.

If one would take the trouble to observe, one could multiply similar examples without difficulty.

It must be remarked that in the case of which we have just spoken, the injurious species are very injurious only from time to time in a rather periodical manner. Several years will occur in a given region when they are not mentioned. Then, under the influences of certain conditions, they multiply for two or three years in an excessive way, giving rise to terrible invasions, until the parasites favored by this great development of the host species become themselves sufficiently multiplied to bring about the retrocession. This repressive and regulating action of the parasite, having for its object the limiting of the increasing abundance of the plant-feeding species, moves then in a successive periodical manner, which recalls a little the action of the siphon of an intermittent fountain. This type of injurious species, with great invasions more or less separated and presenting a periodical character, is met with especially with those species which attack plants cultivated upon a very large scale, and corrects an unstable equilibrium which man himself has provoked by the establishment of great homogeneous cultures. Exception, however, should be made in regard to certain migratory and omnivorous species, such as the grasshoppers and crickets, whose invasions seem to exist during all time and without any correlation with cultural conditions.

In other cases which more nearly approach the general and primitive law of nature, the injurious species maintains always about the same rank, and the fluctuations which it presents are only of secondary importance. The parasites act as a moderating check to the continued increase, and prevent the injurious species from multiplying in an excessive manner. They are themselves present in almost constant number from one year to the other. Their rôle is not only to bring back an injurious species to a small number of indidivuals when it has passed the mean, but to hold it constantly at a numerical point much below that which it would reach without their presence.[3]

It is very certain, however, that in nature all the intermediate stages between these two types just mentioned are to be found, and these two types themselves, as we admit, are more theoretical than real.

[3] The condition by which the fraction of parasitized insects remains constant from year to year is represented by the equation: $\frac{c}{b} = \frac{a-1}{a}$; c representing the number of eggs laid by an individual of the parasitic species, b the number of eggs laid by an individual of the plant-feeding species, and $1/a$ the proportion of parasitized insects. (Bellevoye & Laurent, *loc. cit.*) In other terms, if a quarter of the insects are parasitized, it would be necessary, in order that this proportion should remain constant from year to year, that the fecundity of the parasite should be to that of the host as three is to four.

The conditions and factors which control the relations of beings among themselves are so numerous and so complex that to interpret them and render them intelligible one is forced to speak more or less theoretically in considering only certain of the causes and in momentarily omitting the others.

In fact, the regulation can in no case be considered as the exclusive result of the action of any given parasitic species, of which the fecundity will be proportioned to that of the host species and in such relation that it maintains a constant numerical tax.

The fecundity of the parasitic species is only one of the factors which determines this equilibrium. If it is true that it is of prime importance, that fact should not prevent us from taking account of the others. There are a number of these, as follows:

First.—The hyperparasites, or secondary parasites, living at the expense of the primary parasite, and having themselves tertiary parasites.

Second.—The coparasites, that is to say, other species living in the same host.

Third.—Other plant-feeding species occurring with the host species.

Fourth.—The enemies of all insects (insectivorous birds, etc.), attacking both the plant-feeding species and the parasitic species.

Fifth.—Climatic conditions influencing in a favorable or in an unfavorable way either the host species or the parasites, the hyperparasites, or the enemies of all kinds liable to attack the insect.

Sixth.—The rapidity with which the generations are developed,—of the host species, on the one side, and the parasitic on the other.

Seventh.—The tendency in the plant-feeding species to retard the development of certain individuals of a given generation for a longer or shorter time.[4]

[4] Factor No. 7, taken alone or combined with the preceding factor, has a prime importance in preserving the host species from destruction by the parasitic species. Three examples will serve to illustrate this:

First Example.—Encyrtus (*Ageniaspis*) *fuscicollis* is a hymenopterous parasite whose power of prolification is immense, since, as I have shown in an earlier memoir, it presents the very exceptional phenomenon of polyembryony, that is to say, that a single one of its eggs can give birth to more than 100 individuals, capable of multiplying in this way.

Now this *Encyrtus* lays its eggs in the eggs of a moth of the genus *Hyponomeuta*, which has only a single generation each year, as has the *Encyrtus* itself. Under these conditions it may be asked how the *Hyponomeutas*, instead of being promptly annihilated, are, on the contrary, capable of multiplying in certain years to the point of being destructive to fruit trees during their larval stage, and this in spite of a number of other parasites, particularly Tachinids. The reasons are certainly numerous; but the one to which we wish to call attention is, that the time of the swarming of the *Encyrtus* is notably shorter than the egg-laying period of the *Hyponomeutas*. However immense may be the number of Encyrtids that appear in a season, one may be certain that all of

Eighth.—A faculty similar to the preceding which the parasite may possess.[5]

the eggs of the *Hyponomeutas* are never parasitized, and the adult generation of the *Encyrtus* will already have disappeared while the *Hyponomeutas* still continue to lay eggs, which will thus escape the parasite.

Second Example.—With the Hessian fly, a small dipterous insect whose larva is extremely injurious to wheat, the generations succeed one another the whole year, and under particularly favorable conditions there can be five or six generations in a single year. However, the time necessary for an individual tc perfect its development is extremely variable, according to conditions in which the pupæ find themselves, and especially in regard to their position on the plant—whether on the green part or near the earth or even dry stubble. Some can complete their development in two weeks, while others, finding the conditions of dryness exceptionally long, wait even as long as two years before issuing. The hymenopterous insects, living at the expense of the insect, which may appear in innumerable quantities, have, on the contrary, only two generations each year at the maximum, and appear only at a definite time, and during a lapse of time of usually short duration. Now, since the parasites never attack more than one of the developmental stages of the insect—egg or larva, according to parasitic species—it results, from what precedes, that there will always be, at the period of egg-laying, existing individuals of the species which will escape them because they are in a developmental condition in which they are not pierced; and when the generation of parasites has passed, these individuals will remain unharmed and constitute the indispensable reserve for the perpetuation of the species. It is not necessary that this reserve should exist throughout the range of the plant-feeding species. On the contrary, they may be annihilated in certain localities by a combination of climatic conditions or factors of some other nature having an unfavorable influence, and it is in this way that the local disappearance of certain species, of which this one is an example, is to be explained.

Third Example.—In the preceding case the average conditions, and in particular the relative dryness, play a part of the first rank in the determination of retarded development, and the adaptation of the plant-feeding species enables it to react in a more or less energetic manner to external influences. In other cases the plant-feeding species has acquired a great variability in the time necessary for the development of individuals. This variability, which appears to be independent of average conditions, consists in reality in the fact that different individuals present a variable power of reaction to identical external influences.

It is thus that, according to Boisduval ("Essay on Horticultural Entomology," Paris, 1867, p. 15), the chrysalids of *Bombyx everia* and *lanestris*, which cause great damage in Germany, issue in a very irregular manner. "One sees," says he, "moths of these Bombycids issue in September after three months of metamorphosis, others in the spring of the following year; but what is more astonishing is, that from the same egg laying, from the same brood of caterpillars, reared under the same conditions, the moths have issued during seven years in April and September—a wise foresight on the part of nature, which does not wish to expose the species to sudden destruction."

[5] This factor, which favors the parasitic species, is in conflict with factor No. 7. Some very remarkable examples of this have been given me by M. Künckel d'Herculais concerning egg-feeding parasites of locusts (Cantharids, Clerids and Bombyliids), the development of which in certain cases can be retarded for several years, thanks to a condition of torpidity which the larvæ

There exists an intimate relation between all these conditions, and this relation binds in a particularly striking manner the plant-feeding insect and parasites which live at the expense of the latter. The harmony which results from the mutual adaptation of these beings should not be surprising, since it is the condition *sine qua non* of the existence of the species. From the reciprocal actions which they exercise upon one another, results the equilibrium in which they are maintained.

II. Perturbations brought by Man in the Natural Equilibrium

The intervention of man in disturbing the laws of nature is capable of breaking this natural equilibrium, and of bringing about in the existing order a perturbation from which he is perhaps the first sufferer of serious consequence. This rupture can be occasioned by two principal causes: (1) by new conditions created for insects by cultures; (2) by the accidental carriage of certain species from one country to another.

1. *Perturbations provoked by New Conditions created by Cultures; Methods bringing about the reestablishment of the Equilibrium*

Man, in planting over a vast extent of country certain plants to the exclusion of others, offers to the insects which live at the expense of these plants conditions eminently favorable to their excessive multiplication; for he diminishes in their favor the difficulties of their struggle for existence and often favors their alimentary specialization, while the food-plant, in the conditions which it finds itself, is not always capable of reacting by defensive adaptations of sufficient compensating value.

In this case, man, in order to regain the equilibrium favorable to his own interests, should have recourse to a regular rotation of crops, destined to interrupt the life cycle of the injurious species, and to all methods possible to increase the resistance of the plant. But also the beneficial insects whose useful rôle is incomparable should be watched. It is necessary to aid or at least to start their work; and, finally, in any circumstances it is necessary to know them in order to protect them in a judicious way, and above all not to destroy them by inopportune cultural practises.

Protection of Beneficial Insects.—Apropos to the Hessian fly, we may enter into. "The retarded development of these parasitic larvæ," says Künckel, "enables the successive issuing of adult insects during several years, and is evidently in close correlation with the appearance of the locusts; the latter, decimated, fly from their enemies to reproduce far away; the former awaiting their return to insure the well-being of their progeny; thus is established a regular balance between the multiplication of the locusts and that of their egg-feeding parasites, which assures the perpetuity of both species."

have elsewhere insisted upon the fact that one of the measures most often recommended—the destruction of the stubble remaining in the field after the harvest—may have unfortunate consequences, for doing this in a tardy manner one risks intervening at a moment when all of the flies have emerged and have abandoned the stubble, exposing to destruction only the parasites whose part would have been to stop the invasion the following year.

Kieffer has pointed out a remarkable analogous fact for a Cecidomyiid, namely, *Diplosis tritici,* attacking not the stubble, but the grains of wheat, and has shown that one of the measures which has been advised—burning the debris after the threshing—has only an injurious effect, for while it is true that this debris contains pupæ of the midges, it should be remembered that the healthy and nonparasitized larvæ of these flies transform in the ground, while those which remain in the heads are, on the contrary, parasitized.

In the cases which we have just mentioned, the protection to be accorded to the parasites consists solely in abstaining from inopportune measures capable of bringing about their destruction without any advantage whatever. In other cases it is an active protection which has been advised, and which comprises operations destined to insure the survival of the parasites.

It is in this way, for example, that Decaux, struck by the multitude of ichneumon flies, or Braconids, which came out of the buds of apple attacked by *Anthonomus,* advised, in place of immediately burning these buds as was generally done, preserving them in boxes covered with gauze, raising the latter from time to time during the period of issuing of the parasties so as to permit them to escape. In 1880, he put this method into practise and collected in Picardy buds reddened by the *Anthonomus* from 800 apple trees, amounting to 5 hectoliters; and thus accomplished the destruction of more than a million Anthonomi, and set at liberty about 250,000 parasites which the following year were aids in the destruction of the weevils. The orchards treated being isolated in the middle of cultivated fields, it sufficed to repeat the same operation the following year in order to stop all serious damage during ten years.

This plan started by Decaux has been perfected by Berlese (1902) in order to protect the parasites of the Cochylis. This author recommends the use of boxes with the cover pierced by a window, being also covered by a metal plate perforated with holes 2 mm. in width. In the autumn there is placed in the box nearly full-grown larvæ with the leaves necessary for pupating. In the springtime the parasites will issue through the openings, while the moths perish in the box.[6]

[6] If it is desired to preserve the parasites for study, the perforated plate is covered with a bell glass, in which the parasites accumulate without ever reentering the dark box.

There is no reason why this method should not be adopted on a large scale, replacing the box by a room in which the window is closed by means of a wire screen. A similar method could be employed with a number of other insects, and quite recently (1907) Silvestri has advised it for the olive fly in arranging a plan of defense against this insect, based both upon the protection to parasites and on cultural methods.

Against the injurious scale insects of the *Aspidiotus* group it will be particularly easy to put into practise a similar method, and it will give good results. It will not be necessary to burn during the winter time the branches taken from attacked trees, but to collect them in the neighborhood of the infested trees. *Aspidiotus,* which can live only upon living plants and are incapable of traveling, will thus perish by inanition. Parasites living at their expense can easily, upon issuing, gain the fruit trees. In the same way, if one is using insecticidal measures, it will only be necessary to remove the cut-off branches or cut-down trees to sufficient distances so that they will not be touched by the insecticides. It is necessary to have seen the parasites of scale insects at work; it is necessary to have observed that the immense majority of those which cover a tree are often eaten and perforated by one or several regular, round holes through which the parasites emerge, in order to understand how such measures are justified.

Johnson, in 1899, having put some fragments of twigs covered with the San Jose scale in a series of tubes, obtained more than a thousand parasites (*Aphelinus fuscipennis* Howard) in each of them. Struck by this observation, he recommended the protection of this *Aphelinus* by the application of such measures as we have mentioned.

Berlese, in 1902, suggested the same method in the struggle against *Diaspis pentagona,* one of the most dangerous enemies of the mulberry, in Italy.[7]

There still exists a method entirely different from that which precedes, but whose end is also to protect parasites and to assist in their multiplication. It consists in encouraging, or cultivating in the neighborhood of the plantations, wild plants which harbor them.

Thus, for example, parasites of the olive fly do not live exclusively upon that insect, but also upon certain gall insects of the oak and the briar rose. Therefore, it has been recommended to preserve in the neighborhood of the olive groves, bushes or hedges of these plants, or even to transport galls into the olive groves.

Some authors, struck by the eminently useful part played by parasites in certain invasions of insects, have actually advised the abstaining from destructive measures in fear of killing at the same time parasites

[7] Berlese is of the opinion that winter treatments for scale insects should be discontinued, on account of the great number of parasites destroyed by them. We can not adopt this opinion, for reasons which we shall give later on.

which they harbor, or the predaceous insects which destroy them. This way of looking at the question is very exaggerated. It is only in case where the parasites constitute restricted and very localized centers of contamination that this idea can hold for these determined points, admitting that it will still be possible to utilize such centers of propagation. In the great majority of cases, on the contrary, it must be said that however useful parasites may be, the fear of destroying them ought never to prevent the undertaking of all measures having for an end the direct destruction of the injurious insect. Parasites act, in fact, only at a more or less long maturity, and admitting that with an invasion of caterpillars the majority or even all harbor in their interior larval parasites, they will none the less accomplish the greater part of their depredations in a manner quite as complete as if they were not parasitized. Should we, then, allow them to devastate a field or orchard in order that the parasites can, the following year, accomplish their beneficent work? An intervention with destructive methods, far from being dangerous, will permit us, on the contrary, always to obtain a double result: first, it will immediately stop the damage and save in a more or less complete manner the products of that year; and, second, it is not likely in the great majority of cases that the caterpillars will be more abundantly parasitized in that particular spot than in any other portion of the country; and in destroying a certain number of non-parasitized caterpillars, one will diminish for the whole region the number of possible adults which would assure the generation of the following year, and that without changing the existing proportion between the parasites and the representatives of the injurious species.

The assertion that insectivorous birds can cause more harm than good by attacking either the useful species or larvæ parasitized by them, does not appear to us well founded and seems to us to be refuted by analogous arguments. In spite of the thesis formerly proposed by Perris, and ably defended of recent days by Berlese and Severin, the protection of insectivorous birds appears to us not at all as susceptible of thwarting the beneficent action of useful insects.

Utilization of Indigenous Insects in the Fight against Indigenous Injurious Species.—Aside from the intelligent protection which should be given to beneficial insects and which, as we have just shown, can be based only upon exact knowledge of their biology and the relations which they have to other organized beings, can man assist in artificially multiplying them, and making of them a forced subject to his will which will serve him at will in the struggle against indigenous enemies of cultivated plants—those which for centuries have devastated our prairies, fields, orchards and forests?

The fungous parasites and microbes have already been brought into our arsenal, from which we draw against the enemies of agriculture. Can we bring in entomophagous insects in their turn?

While they habitually accompany injurious insects wherever they are found, it may happen in a restricted region and an isolated plantation that the beneficial forms are absent, and there will be undoubtedly a benefit in introducing them. It often happens that coniferous forests are ravaged by insects without any of their most important enemies, such as *Calosoma sycophanta.* Will it not be opportune in such a case to transport a lot of these beetles from the region where they exist and acclimatize them in the devastated forests, where they have not appeared naturally?

Then also with sedentary insects, such as the scale insects, which develop often in closely circumscribed localities, it will be possible, when one chances to find a colony particularly invaded by parasites, to cut off certain branches and carry them into other orchards infested by scale insects and less favored from the point of view of the presence of parasites.

In 1871–72, Le Baron, in the United States, made some experiments in the transportation of the small hymenopterous parasite, *Aphelinus mytilaspidis,* from one locality to another, attaching the branches covered by parasitized scale insects to infested trees which were found in a region where the Chalcidid parasite did not exist. At the end of the year it was stated that the parasite had become domiciled in that locality.

Johnson has noticed that another parasite very close to the preceding, *Aphelinus fuscicollis,* may be extremely abundant in certain localities invaded by the San Jose scale, and be totally absent, on the contrary, in others, and he succeeded in propagating this insect by suspending upon a tree, at small distances, small baskets containing twigs covered with parasitized scale insects.

In France, Decaux was the promotor of the same method, and in 1872 had the honor of attracting attention to the question, making experiments in the transportation of parasites from one locality to another. However justifiable such practises may be in certain determined cases, one can not deny that they have not the certainty which they should have in order to be perfectly convincing. In fact, with an indigenous species, it is very difficult to say that it is, at a given moment, really absent from a locality. If it is absent to-day there is a great chance that it will appear to-morrow, coming from a neighboring region. The experimenter will find himself also exposed to possible criticism, not without reason, that he has attributed a result to his own work when nature would have perfectly accomplished the same thing without his intervention.

A more profound study of parasites and predaceous insects—of their development, their migrations, their geographical distribution—will show us without doubt and in a more precise way, the real value of the consistent method to be used in transporting indigenous parasites, and thus assisting in their spread. In any event it suffices to say that actually it appears applicable in a rather limited number of cases.

2. *Perturbations brought about by Accidental Importations. Reestablishment of the Equilibrium by the Introduction of Predaceous Insects and Parasites*

The point of view becomes quite different if, in place of considering the perturbations which man has provoked by the substitution of homogeneous cultures for the primitive vegetation of the soil, we look at what he has accomplished in accidentally introducing, by commerce, a plant-feeding insect into a country where it had not previously existed and where it finds conditions favoring its development. It is readily understood that the chances are great that this species will be introduced without the procession of parasites and predatory species which limit its propagation in its original home. It can notably be imported without the parasites which are especially adapted to live at its expense, or often, indeed, without a single one of its natural enemies, and then finding itself unhampered in its multiplication, the injurious species takes prodigious strides and becomes a scourge infinitely more redoubtable than in its own country.

In such a case everything indicates the value of an endeavor to reestablish the equilibrium by introducing into the invaded country all the auxiliaries capable of checking the plague.

In the United States it has been ascertained that nearly one half of the injurious insects of the first importance are of exotic origin and have been accidentally imported into the country, so it is not astonishing that it is America which has started the method which consists in fighting the enemies of agriculture by means of their parasites and that in that country it has taken on a prime importance. After several fruitless efforts with different insects, Riley, in 1883, succeeded in bringing about the first true acclimatization of a beneficial insect, in importing from England into the United States a small hymenopteron of the family Braconidæ, *Apanteles glomeratus,* which is a parasite of the larvæ of the cabbage butterfly (*Pieris brassicæ*). This experiment, however, was only against an enemy of secondary importance, and in order to popularize the method a striking success was necessary—an unprecedented triumph against one of the most redoubtable enemies of cultivated plants. This occurred with a small Coccinellid, *Novius cardinalis,* which brought about this decisive victory. The history of this insect and the work which it has accomplished in the country to which it was introduced is of such importance that we will give a somewhat detailed recital.

The Use of Novius Cardinalis against Icerya

Icerya purchasi and Novius cardinalis in America.—*Icerya purchasi* is a scale insect living upon different trees and particularly upon citrus trees. It is originally from Australia, and was accidentally introduced, about 1868, into California where it did enormous damage, and threatened to ruin the cultivation of oranges and lemons. All attempts to fight this Australian insect with different insecticides were vain. It continued to spread in a progressive manner from the orchards that had already been annihilated or were in bad condition.

Riley, then director of the Division of Entomology of the Department of Agriculture, at Washington, thought of utilizing the natural enemies of the scale insect. Ascertaining that in Australia, its original home, it did not seem to be seriously injurious, and to be without importance from the economic point of view, he was led to think that it probably was held in check there by parasites. Investigations which he made on this question having confirmed his ideas, he made every effort to accomplish the desired end, namely, the acclimatization of the natural enemies of *Icerya* in California. Finally, after numerous appeals to the government, he was able to arrange for a sending of two agents of the Division of Entomology to Australia on the occasion of the exposition at Melbourne, in 1888, with a credit of $2,000. One of these agents, Mr. Koebele, was especially instructed to search for parasites of *Icerya.*

On his return he brought a collection of the natural enemies of the Australian scale insect. Among these there were a hundred living specimens of *Novius cardinalis.* It multiplied so rapidly that in the following year, 1889, they could distribute to the fruit growers of California 10,000 specimens. A year and a half after its introduction it had relieved the region from *Icerya,* and had reduced their number to a practically negligible quantity. According to witnesses this deliverance possessed for the inhabitants of the country an almost miraculous character. Immense groves of oranges bearing no fruit, covered with a horrible, white leprosy composed of the *Iceryas,* and which seemed irremediably lost, suddenly took on a new vigor and furnished abundant crops. Now the only natural means necessary to hold *Icerya* in check consist in sending a small number of *Novius cardinalis* to start colonies in the district where the scale insect shows a tendency to regain its foothold. In this way reserves of *Novius* are constantly kept on hand for exportation, either to the different districts of the State of California or to foreign countries, and the State Board of Horticulture of California has constructed small boxes of glass and wire gauze of octagonal form, 16 feet in diameter and 18 feet high, allowing the *Iceryas* and the *Novius* to live upon the trees surrounded in this way.

In 1894, at the opposite extremity of the United States, in the State of Florida, a new invasion of *Icerya purchasi* was produced, and the scale insect was introduced, this time under conditions which show very well the risks attending such attempts to acclimatize useful insects when they are made by incompetent persons. A nurseryman in Hillsboro county, Florida, having heard of the extraordinary services rendered by the Australian ladybird, being ignorant of the fact that this insect will not attack other insects than *Icerya,* sent to California for *Novius cardinalis* to fight the *Aspidiotus,* or other scale insects, feeding upon their plants. The *Novius* was naturally sent with some *Iceryas* which would serve as food for it on the journey, and they were all placed together by the nurseryman upon the trees which he desired to protect. No one knows what became of the *Novius,* but the *Icerya* multiplied and was not slow in covering the trees upon which it had been placed. Radical measures were almost immediately taken; all the trees attacked were burned; and for four years nothing was heard of the insect. It was believed to have been entirely exterminated, but in 1898 the presence of specimens of *Icerya* was discovered. The formidable scale insect was found at this time at several points near the locality where it had been first imported, and it had invaded one or two orange groves. It was necessary to give up all hope of exterminating the species, and an immediate effort was made to introduce *Novius cardinalis.*

Mr. Gossard, state entomologist of Florida, and Mr. Al. Craw, entomologist of the State Board of Horticulture of California, directed the work. The *Novius* was at first colonized with success in two of the infested orchards, and in 1900 had become sufficiently well established to enable them to distribute it in good number in infested localities. It seems to be certain that *Icerya* finds in Florida conditions less favorable to its development than in California. It has been stated that it is attacked there by a fungous disease. In any event it can not be doubted that with the assistance of *Novius cardinalis,* it will never play in Florida the injurious rôle which it has played on the Pacific coast.

America is not the only country which has suffered from the introduction of *Icerya purchasi.* This insect has been imported, or was imported at almost the same time, into South Africa; and more recently it has made its appearance in the Sandwich Islands, in Portugal and in Italy. *Novius cardinalis* has in these cases been sent for, and the success has been as complete as that obtained in California.[8] The history of these successive invasions and of the efforts which have been made to combat them conveys useful instruction and is worthy of our attention.

Icerya purchasi and Novius cardinalis at the Cape.—About 1890,

[8] *Novius cardinalis* has also rendered great service against *Icerya* in New Zealand.

Icerya purchasi having been at the Cape already for some years a great subject of alarm, the Secretary of Agriculture, at Capetown, made an effort to secure *Novius cardinalis* from Australia and from New Zealand, but the correspondents to whom he wrote had not been able to collect a sufficient number to make a sending, and a demand was made upon the Department of Agriculture of the United States. Following the year 1891 an ample provision of larvæ and pupæ was sent from California to the Cape. But on account of the length of the voyage, no living specimens arrived. At the end of the same year, Mr. Thomas Low, member of the Legislative Assembly of the Cape of Good Hope, went to the United States, charged by his government with a mission connected with different agricultural questions, and notably to secure the sending of *Novius cardinalis.* He procured three boxes full of this insect, and left New York the twenty-third of December, 1891. One of these boxes was placed in the ice-box of the steamer. He kept the two others in his cabin, feeding the *Novius* regularly during the journey with *Icerya.* The three lots, including those preserved in the ice-box, arrived in perfect condition, and on the twenty-ninth of January were placed in the hands of the Secretary of Agriculture of the Cape.

The insects were then utilized in the following way: a small number were placed in the open air upon an infested tree in the botanical garden at Capetown; but the majority were used for rearings in captivity. Some were placed upon an infested orange tree which was surrounded by a great wire-gauze cage, while others taken to a different locality were placed in a sort of glass house constructed around the orange tree, and similar to those used in California for the same purpose.

The efforts destined to naturalize *Novius cardinalis* in South Africa were reinforced about the end of 1892 by a new sending coming from Australia, and sent by Koebele, who was then on a mission to that country.

To-day the *Novius* is perfectly naturalized at the Cape. In some spots which are particularly exposed to cold and where the winter is very vigorous, they succumb to the low temperature, and the Entomological Service is obliged to frequently renew the colonies. This, however, is exceptional, and almost everywhere the *Novius,* perfectly acclimatized, holds the *Icerya* in check so efficaciously that since several years they have not worried about it.

Icerya ægyptiaca and Novius cardinalis, in Egypt.—About the same period several attempts were made to introduce *Novius cardinalis* from California into Egypt, not to fight *Icerya purchasi,* but an allied species, *Icerya ægyptiaca,* which is of unknown origin and for several years had been found in the gardens of Alexandria, where it did great damage to the oranges, lemons and figs. The first attempts failed on account of the length of the voyage, but a new attempt made about the beginning of the year 1892 was crowned with success. Six adult insects and several of the larvæ arrived in living condition at Alexandria. They were set at liberty upon an orange tree infested with *Icerya ægyptiaca,* and accommodated themselves so well to this new food that in a short time they had become so numerous as to cause an almost complete disappearance of the *Icerya.* But later the *Icerya* again began to increase. Happily, however, the *Novius* had not entirely died out and it also recommenced to multiply, and, thanks to the successive see-saw movements between the two species, the *Icerya* is held in check in a definite way.

Icerya purchasi and Novius cardinalis in the Hawaiian Islands.—In the Hawaiian Islands, the alarm provoked by the invasion of *Icerya purchasi* was of short duration. The injurious insect was discovered in 1889 in the suburbs of Honolulu, and multiplied there with rapidity. In 1890, *Novius cardinalis* was in its turn introduced from California, and a year afterwards the trouble was entirely stopped.

Icerya purchasi and Novius cardinalis in Portugal.—In 1897, the presence *of Icerya purchasi* was discovered in the orange groves around Lisbon, and the agricultural population began to be alarmed. This insect had multiplied already for several years along the banks of the Tagus River, and it seemed that the first infested plants had been brought from the Azores, where for a long time the Australian scale insect had existed.

In 1897, almost all the gardens of Lisbon and its suburbs were infested with *Icerya,* and the insect was known to occur in 32 localities. Before attempting the introduction of the natural enemies of the Australian insect, they tried insecticides which were found insufficient to stop the scourge, but which, nevertheless, were of much service from time to time, when it was deemed desirable to introduce *Novius cardinalis.* Messrs. de Silva and Le Cocq were particularly interested in this latter matter. In spite of a hostile press and the opposition of the greater part of the administrative authorities, they placed themselves in relations with Mr. Howard, the learned director of the Bureau of Entomology, of the Department of Agriculture of the United States, and he wrote to San Francisco, to the State Board of Horticulture of California, and procured from Mr. Alex. Craw sixty *Novius cardinalis* in the adult condition, as well as a certain number of larvæ in different stages of development.

As soon as they arrived in Washington, in October, these insects were placed in boxes with moss with an ample supply of *Iceryas* for food, and were then sent on to Lisbon. The greater part of the *Novius* perished on the voyage. Five only, coming from larvæ which transformed on the journey, arrived alive at their destination. On their arrival they were placed in breeding cages at the Experimental Agricultural Station of Lisbon, and were cared for in such a fortunate way that in the month of December they had already a numerous progeny.

On the twenty-second of November a second colony of *Novius* was sent to Lisbon. The journey this time, on account of accidental delays, was particularly long, and from San Francisco to Lisbon it lasted not less than 44 days. Five females and one male still lived on arrival, and these received the same care as the others, and the success was such that in June, 1898, these six samples received in December, 1897, had several thousands of descendants. On account of the danger to which we are exposed of some time seeing the orange groves of the south of France and the north of Africa invaded by *Icerya,* we believe that it will be useful to give some details as to the methods used in breeding, under the direction of M. Le Cocq. [See pp. 32–37, Bulletin 18, New Series, U. S. Dept. Agriculture, Division of Entomology.]

This method of work, which permits the handling of the *Novius* without touching them, has been practised in Portugal on a large scale, and thanks to this method, they were able to obtain an immense multiplication of the Australian ladybirds, but in order to facilitate the rearing still more and to obtain as great a production as possible, they constructed a large wire-gauze cage after the model already used in the United States.

In 1898, thirty-eight centers of dispersion, in Lisbon and in the suburbs, had been thus established and were in active operation. In the month of August, ninety colonies existed; in September, four hundred and eighty-seven, without counting the secondary colonies started by the orchardists themselves, who had given one another specimens of these precious insects.

The gardens and orchards, which were completely infested and almost ruined, were cleaned of the scourge as if by enchantment. The number of *Icerya* became practically negligible, and all treatment with insecticides was from that time entirely superfluous. In a letter addressed at this time to Mr. Howard, Mr. Le Cocq wrote as follows:

> The multiplication of the *Novius* which you sent in November and December has been astounding. . . . The result exceeds everything that we could reasonably expect. The colonies of *Novius* are now being distributed profusely every day to many farmers and gardeners who ask for them, and you must not doubt that we recognize their just value, and appreciate the exceptional service you have rendered to Portuguese agriculture and horticulture.

However happy these results, it should not be forgotten that the *Novius,* in Portugal as well as elsewhere, has not been able to completely exterminate the *Icerya.* It keeps it from reaching the condition of a pest, but it is not able to prevent its dissemination or its slight increase. Mr. Duarte d'Oliveira, of Oporto, to whose kindness I owe certain interesting documents upon the history of *Icerya* in Portugal, has written me that he has recently found several colonies of this insect in the north of the kingdom, in the province of Traz-os-Montes, where it had previously made its appearance.

Icerya purchasi and Novius cardinalis in Italy.—*Icerya purchasi* was introduced accidentally into Italy at the end of the year 1899 or in the spring of the year 1900, without any indication of the origin of the infection. But it was observed for the first time, in the month of May, 1900, at Portici, near Naples. It was there found in a little garden upon orange trees, and was represented only by a rather small number of individuals. The proprietor of the garden, ignorant of the character of the insect and of the danger arising from its presence, took no trouble to destroy it, and the scale insect, able to develop freely without enemies, spread so rapidly that in the autumn it already covered the bark and leaves of the oranges upon which it had first been observed. Startled at this sudden invasion, but not yet deciding to apply to competent persons, the owner of the garden tried to stop the trouble by cutting down the most infested trees without bothering himself with those that were not badly infested, so the infestation continued. The eighteenth of November, the same year, the entomological laboratory was notified of the occurrence; and Professor Berlese, the director of the laboratory, recognized the species as *Icerya purchasi*. The insect was still very localized, and it was found at this time only in the adult condition in the little garden which was the center of the infection, and upon a large bay tree which occurred in another neighboring garden, occupying a high position and whose branches overhung the infested garden. This bay tree, on account of the strong winds which blow at that time of the year, constituted a center especially favorable to the dispersion of the larvæ into the surrounding trees, and, in fact, the larvæ were found in all the little gardens about. An examination was made and it was found that the infested area did not exceed one hectare.

On account of the small spread of the insect they tried to exterminate it by an energetic application of insecticides. The first thing done was to cut down the bay tree, which was the principal center of diffusion, and to burn it after having cut off and disinfected all the branches bearing leaves. In the infested gardens all the affected trees were cut back and all the branches were disinfected with a solution of rubina.[9] The low-growing plants were treated with sprayings of the same insecticide. They hoped to rid these of the insects in this way, but in the following spring living larvæ, still very numerous, were found crawling over the plants treated, and then, despairing of destroying them with insecticides, they had recourse to *Novius cardinalis*. At Professor Berlese's request successive sendings were forwarded from

[9] Rubina is a mixture of equal parts of soda and tar, recommended by Berlese, and very much employed in Italy.

Portugal by Mr. A. Le Coeq, director of agriculture, and by Mr. L. O. Howard, director of the Bureau of Entomology, of Washington. With the assistanee of the material thus obtained it was possible to make at the entomological laboratory, at Portici, a methodical rearing of the beetles. Different methods were employed and on June 8 the first distribution of *Novius*, of both sexes, was made in the garden which had been the center of infection, the *Icerya* having made rapid progress and the garden being again infested by legions of *Icerya*.

June 28 other similar distributions were made in the other neighboring gardens.

The insects prospered marvelously, rapidly seeking the *Iceryas* wherever they could find them. It should be remarked that *Novius*, once acclimatized in a region, knows very well how to find trees attacked by *Iceryas*, even when they are some distance away. Therefore it is not absolutely necessary to distribute them to all points. In July the results were already evident: One could hardly find patches of *Icerya* which did not show the work of *Novius*, and at the end of the month it was difficult to find adult *Iceryas* with which to continue its breeding in the laboratory to afford food for *Novius*. By the end of autumn there was only here and there a rare individual that had escaped the massacre. In 1902 the intensity of the invasion was entirely minimized, but under the influence of the winds the area of dispersion extended to about a kilometer. Very fortunately the *Novius*, which had become very rare, reappeared. According to information very obligingly sent to me by Mr. Leonardi, of the laboratory at Portici, they still continue to-day to fill in a marvelous way the rôle which devolves upon them, and their naturalization can be considered an accomplished fact. This single fact alone indicates, without any need of further evidence, that they have not exterminated the *Iceryas*.

If they have reduced the multiplication of the scale insect to the point of rendering it practically negligible, it is none the less true that the original infestation persists, and that the area of distribution of the scale insect is slowly enlarging.

The *Icerya* is met with to-day not only at Portici, but in all the little towns around Vesuvius, and all the gardens of Naples have it in greater or less quantity. It is probable that the area will always exist about the first locality. If the beneficent ladybird did not exist by the side of the scale insect, the culture of oranges and lemons would be seriously interrupted, and in a few years throughout the whole Mediterranean region.

(*To be concluded.*)

THE CHILDREN'S MUSEUM AS AN EDUCATOR

BY ANNA BILLINGS GALLUP, B.S.

CURATOR, CHILDREN'S MUSEUM, BROOKLYN INSTITUTE OF ARTS AND SCIENCES

THE Children's Museum is the only museum of its kind in the world. Although it has not reached its tenth birthday, it has won a permanent place in its own community and has awakened in this and foreign countries an interest in new lines of educational advancement suggestive of greater possibilities.

The origin and early history of this pioneer museum illustrate the power of small beginnings. Its life commenced in the residence of an attractive suburban estate which the city had taken for a public park, the Brooklyn Institute of Arts and Sciences having leased the house as temporary store room for its scientific collections. Upon the opening of the Central Museum of Arts and Sciences and the consequent removal of the most valuable institute property, the utility of the old residence would have been at an end had not its picturesqueness of situation suggested a branch museum for the benefit of children.

In December of that year, 1899, therefore, the Brooklyin Institute trustees opened to the juvenile public two small rooms of the Bedford Park building. Although the original exhibits consisted of little more than a few insects, shells and stuffed birds, the eagerness with which children sought them proved the necessity for enlarging the scope of work.

Some of the aims in establishing this children's branch were: to form an attractive resort for children tending to refine their tastes and elevate their interests; to create an active educational center of daily help in connection with school studies; and to suggest new subjects of thought for pursuit in leisure hours.

The method of procedure involved first, the necessity of collections attractive and stimulating to children and also helpful to the teachers of those children; second, a system of instruction that would lead to profitable results through voluntary endeavor on the part of the child.

The formation of suitable collections and the work of putting instruction on a practicable basis have involved the expenditure of time, as well as labor and money. But that progress has been made is shown in the contrast between the original collections and the twelve exhibition rooms of to-day furnished with specimens, models and pictures related to nearly every phase of children's intellectual interests.

THE CHILDREN'S MUSEUM BUILDING IN BEDFORD PARK, BROOKLYN, NEW YORK, a branch Museum of the Brooklyn Institute of Arts and Sciences.

These collections illustrate zoology, botany, United States history, mineralogy, geography and art. They are attractive in appearance, simple in arrangement and labeled with descriptions adapted to the needs of children, printed in clear readable type.

Our zoological collections are installed in five rooms, whose contents are prepared for children of varying ages. The youngest children seek the room of "animal homes," where common mammals and birds of Long Island are to be found with their nests and young. High school pupils make use of synoptic exhibits and particularly of the insect room with its local insects, life histories of common forms, and living bees, ants and silkworms. Bird exhibits attract and delight visitors of all ages from the two-year-old baby, who can only say "Chicken, chicken" as he points his chubby fingers indiscriminately to the condor, albatross and flamingo, to the white-haired grandparent whose "hunting days" are recalled by the mallard duck and grebe.

That their conceptions of geography may not end with maps, globes and charts, we employ model groups to acquaint children with remote peoples of the earth, especially type races from the various zone belts. One of these scenes depicts the life of the Eskimo, his costume, shelter, implements and industries. The story of his life struggles and the influence of his environment on appearance and conduct are easily understood. From the comparative study of an increasing number of such models, children readily perceive the importance of climate and physical features of localities in determining human settlement, industries and commerce.

It is as practicable to annihilate time as space by the use of model groups, therefore when our children study colonial history the miniature scenes at the museum carry them back into the period when the nations of Europe were establishing permanent colonies in this country. The men and women, dress, homes, social life and customs of those early days become a reality to the child who lives in imagination among these little "doll people" with whom he delights to be. The relics, manuscripts, pictures and arms, in other parts of the historic collection have a new interest for him after he has learned to relate them to their respective historic periods.

A children's museum library occupies two rooms in the museum building, and is a part of the museum work. Its 5,000 volumes comprise the best works on natural history, in its broadest sense, and closely related subjects. The library supplements the work of the museum in providing books useful to its staff in preparing collections, in furnishing additional information to visitors and in offering books on the lines of school work for the benefit of teachers and pupils. Two trained librarians in constant attendance enable visitors to consult books without formality; and through an acquaintance with the contents of school curricula, the exhibition materials of the museum, and most important of all, the children themselves, the librarians not only furnish desired information, but guide and direct the tastes of young readers. Further than this, the library shows to parents and teachers the most interesting and helpful nature books, and aids them in selecting those best suited to the needs of their children.

Children's Museum Library occupying less than 600 square feet of floor space, yet accommodating at times between 300 and 400 readers in one day.

In the absence of official relations with public or private schools the museum makes no demands on its visitors. It offers its privileges free to children of all ages and leaves each one to choose his own method of enjoyment. Whether he copies a label, reads an appropriate quotation, talks about the group of muskrats with his playfellows, spends an hour in the library or listens to the explanation of the museum "teacher," who gladly answers his questions and tells him stories, matters but little so long as the effect of his visit is to enhance his love for the best things in life.

Through the *Museum News*, a joint monthly publication of the Brooklyn Institute Museums, principals and teachers in Brooklyn are informed of the half hour natural science, geography, and history talks, given in the children's museum lecture room. Teachers are invited to bring classes to these lectures (which are illustrated with lantern slides, models and experiments) or to study museum exhibits correlated with school work. Some member of the museum staff is always present to render every assistance to visiting classes. Objects and models are taken from the cases and used in demonstration, living specimens from vivaria and aquaria are shown to the nature study classes, questions are answered, in fact everything that can economize the time of the visitors and increase their enjoyment is done. Another privilege extended to schools is the use of stuffed birds, boxes of insects and other "loan material," distributed for class-room study.

The demand for the privileges of a Children's Museum may be seen from the readiness with which schools and individuals accept them. More than 125 schools, many of them remotely situated, send pupils and teachers to our museum; 561 visits from teachers alone in search of definite information were recorded in the school months of 1906, and for the same period the Children's Museum lectures attracted an attendance of 17,253. The average annual attendance for the past five years has exceeded 94,000 visitors.

It would seem from the statistics that a Children's Museum if not a life necessity, is indeed an unquestioned blessing to a great city like our own, whose population is boxed in apartments or brown stone blocks of such vast extent as to place the country beyond the experience of many children. The advantage of a cheerful, sunny, attractive museum rich in natural objects, artistically displayed, where children are sure to find a sympathetic welcome, where they are safe and happily and profitably occupied, is scarcely appreciated until we pause to consider the influence for good or evil of habits acquired in leisure hours, and of the demoralizing influence of crowded city streets and back alleys.

Many of our boys and girls who are now young men and women paid their first visits to the museum in company with their parents or the family nurse. Year by year they have returned to the museum attracted by new features of the work adapted to their growing intellectual needs.

Two years ago, in response to an expressed demand from the boys, the museum began a course of lectures in elementary physics, and in connection therewith invited those interested to come to the museum on certain afternoons to experiment individually with favorite pieces of apparatus. The boys found the utmost pleasure in the liberty thus granted—they experimented under the guidance of a member of the museum staff, they read library books in connection with their experiments and within a few months had set up a wireless telegraph station. The original work of these boys would be a credit to any institution, for they applied themselves regularly and diligently until they had

HIGH SCHOOL BOYS ATTACHING WIRES TO POLE placed on the cupola of the Children's Museum Building for Wireless Telegraphy.

learned to send and receive wireless messages; meanwhile, the experience of placing the station and keeping it in working order had fitted them to take charge of other stations. Early this summer, when the schools closed, three of these "boys" received offers of remunerative positions with one of the commercial companies to take charge of wireless stations on board of ocean-going steamships—to South America, Panama, West Indies, Bermudas, Key West and other places of interest along the Atlantic seaboard. One of the boys, who had learned to collect and mount insects when he came to the museum as a primary lad, made a very creditable collection of tropical insects which he brought to the museum, carefully preserved and labeled with interesting data.

In contrast to the achievements of these boys by a wise use of spare moments, we can but wonder what these hours would have counted for if there had been no museum, no books and no sympathetic personality to offer an occasional useful suggestion.

Some have maintained that physics and electricity are subjects not germane to museum work, and that a museum should remain loyal to its old purpose of collecting, preserving, classifying and exhibiting objects of scientific value. While the original object of a museum should be kept in mind, we must not lose sight of the fact

Mother Crow and Fledglings on the Nest. In the Bird Room.

that a children's museum calls for such modifications and adaptations of methods as will enable children to use it, and here we must remember that the keynote of childhood and youth is action. Any museum ignoring this principle of activity in children must fail to attract them. The Children's Museum does not attempt to make electricians of its boys, nor is its purpose to do the work of any school. Its object is rather to understand the tastes and interests of is little people and to

A FAMILY GROUP OF SKUNKS. In the Room of Animal Homes.

offer such helps and opportunities as the schools and homes can not give. With that, its mission ends, and the success or failure of its work will be proportional to its skill in meeting individual needs.

About a year ago a small boy was discovered in our building leading his eleven-year-old blind brother by the hand and telling him as much as he could about the objects of especial interest. The eagerness with which this sightless lad drunk in every descriptive sentence led the museum escort to ask him if he had ever "seen" a squirrel—"No," he said, "I never touched one, but I have heard stories about squirrels—they have long, bushy tails and eat nuts." The escort then placing a stuffed squirrel in his hand, gave him one of the happiest experiences of his life. To his book knowledge he could now add a real discovery. Nor did his experience at the museum end with the squirrel; his sense of touch taught him many other stuffed animals and birds, besides living frogs, lizards and turtles. There were other museums in Greater New York, and surely far more costly exhibits, but no museum had hitherto found time to give this blind visitor the especial attention his in-

MODEL OF A PARLOR IN A NEW ENGLAND HOME ABOUT 1750. The scene shows an afternoon call from the minister and the family assembled to receive him and serve afternoon tea and cake. The details of furniture, decorations, and costumes are historically accurate. In the History Room.

PENNSYLVANIA MEADOW VOLE GROUP—showing adults, nest, and young. In the Room of "Animal Homes" arranged for young children.

firmity made necessary. Repeated and prolonged visits demonstrated the sincerety of his statement that he felt as though he had come into a new world with "all these animals."

Every September children returning from country outings hasten to tell us of their holiday pleasures, not the least of which is the deeper appreciation of this world of nature of which the museum has given them broader knowledge. Examples of the quickening and stimulating influence of the museum in individual cases could be multiplied indefinitely, and to these could be added the appreciative testimony of parents and teachers, were it necessary to prove by argument its real value to the community. But, happily, the day is passed when its excuse for existence is questioned, or when the Children's Museum is regarded as an extravagant investment yielding small returns. On the contrary, the returns would warrant an increased expenditure, and this seems to be a necessity of the near future.

The present Children's Museum has long since outgrown its quarters. Its exhibition halls, its lecture room and its library are often so over-crowded with eager children as to defeat the objects of their visits. The New York legislature, however, has recently

PERMANENT DWELLING OF THE NORTHWESTERN ESKIMO. In the Geography Room.

passed a bill authorizing the city to erect a new Children's Museum Building at a cost not to exceed $175,000. With the improved equipment thus provided the Children's Museum would not only serve a larger number of children, but would also serve them more efficiently in proportion to expenditure.

Through publications from the German press we learn that certain educators in Berlin are advocating a children's museum for that city. Meanwhile in our own country museums are beginning to feel the importance of giving more attention to the education of children. In large cities the field for smaller museums is always increasing, and one can but hope that the time may soon come when a system of these institutions, each studying and adapting itself to the needs of its particular

FEEDING THE "TREE TOADS." A daily afternoon attraction.

locality, will be working as branches of a large central museum, with its skilled artists, modelers, taxidermists and preparateurs.

As a small museum in a large city serves a moving population, its service to the individual is necessarily limited by a constant change of clientele. Smaller towns, on the other hand, offer conditions for an almost ideal development. The Fairbanks Museum, in the little town of St. Johnsbury, Vermont, is an excellent example of museum leadership in a small center.

Since the Children's Museum has demonstrated its worth to one community there is reason to expect that it will make its way into others and the variety of problems to be solved in adapting its work to new conditions offers one of the most attractive fields of modern education.

THE PROGRESS OF SCIENCE

THE CARNEGIE INSTITUTION OF WASHINGTON

The year book of the Carnegie Institution is always a scientific document of interest, as, in addition to the administrative reports, it contains a summary of the research work accomplished under the auspices of the institution. The report of the president of Harvard University includes brief statements from the heads of departments and laboratories, but as a rule such reports ignore in large measure the real work which a university accomplishes.

President Woodward's report reviews the administrative and scientific work of the year and discusses the question of publication. It appears that the printing of the scientific publications, apart from the expense of editing, administration and distribution, has cost $109,609, while the sales have amounted to $4,078. The "Index Medicus" has cost $51,461, with receipts of $13,837, and the year books have cost $8,416, with receipts of $220. The president expects that 500 to 700 copies of each publication will ultimately be sold, and recommends decreasing the free copies given to authors.

The new geophysical laboratory was completed during the year. It is situated on rising ground in the northeast section of Washington and has been carefully planned with reference to the researches to which it is devoted. The solar observatory on the Pacific coast has been active in construction as well as in astronomical observations. A tower telescopic apparatus has been erected with a vertical telescope of sixty feet focal length. By means of a cœlostat and a 12-inch objective, the solar image is formed and is carried beneath the ground by a spectrograph. The magnetic survey of the Pacific and of certain land areas has been actively continued. Apart from the work at

Geophysical Laboratory.

TOWER TELESCOPE OF THE MT WILSON OBSERVATORY.

the Desert Laboratory, the Department of Botanical Research has studied the conditions of the Salton Sea, and Dr. MacDougal has continued his remarkable experiments, showing that reagents ingested into the ovaries of seed-plants produce new characters which are transmissible and stable. The important work in experimental evolution under Dr. Davenport and in marine biology under Dr. Meyer has produced interesting results. The special new undertaking of the year has been the erection of a laboratory adjacent to the Harvard Medical School for the study of nutrition.

Since its establishment in 1902 the Carnegie Institution has appropriated \$1,356,185 for large projects and \$784,678 for minor projects. In 1904 more than twice as much was spent on minor projects as on large projects, whereas in 1907 more than six times as much was spent on departments conducted by the institution as for minor grants. The institution is thus coming to be a congeries of scientific departments situated in different parts of the country with administrative headquarters at Washington. In the appropriations astronomy and geophysics have been shown special generosity, astronomy having received \$524,925 and geophysics and terrestrial magnetism \$428,500. On the other hand, only \$6,500 has been appropriated for psychology and \$5,900 for mathematics.

While it is gratifying that the Carnegie Institution is able to carry forward on a larger scale work that was being admirably done by Professor Hale at the Yerkes Observatory, Dr. Boss at the Dudley Observatory, Dr. Bauer under the Coast and Geodetic Survey, Dr. Day under the Geological Survey, Professor Benedict at Wesleyan, Professor Davenport at Chicago, Dr. MacDougal at the New York Botanical Garden, etc., it is certainly disappointing that it has so completely failed to become a central force for the organization and the advancement of science, literature and art in this country. If a million dollars had been given to each of our twelve leading universities for the endowment of research professorships and fellowships, more would have been accomplished for science and scholarship. It is, however, none the less true that the establishment of the Carnegie Institution has contributed in large measure to the advancement of science, and Mr. Carnegie's addition of two million dollars to the original endowment of ten million dollars is very welcome.

The Desert Botanical Laboratory.

SIR ROBERT STRACHEY

Sir Richard Strachey, who died on February 12 at the age of ninety-one years, represented the best British traditions. It will be well for us if in the twentieth century we can produce in a democracy men of the type who came from the dominant families of England in the nineteenth century, men having the instinct to rule, adequate to each event as it occurred, uniting scientific research with administrative duties. Sir Richard's brother is also an eminent Anglo-Indian; Lady Strachey, with five sons and five daughters, is an authoress of distinction.

While the scientific work of Sir Richard Strachey does not give him place among the great leaders, it is of wide range and of real importance. His contributions are summarized in the award to him of a Royal medal by the Royal Society in 1897 as follows: "Two of the most recent of these, are recorded in his report, published in 1888, on the barometrical disturbances and sounds produced by the eruption of Krakatoa and in his paper in the *Philosophical Transactions* of 1893, entitled 'Harmonic Analysis of Hourly Observations of the Temperature and Pressure at British Observatories.' These, while important in themselves, are but the last of a long series of valuable memoirs. He was the first to treat scientifically of the physical and botanical geography, geology, and meteorology of the western Himalaya and Tibet. He also first observed the occurrence of a regular series of fossiliferous rocks, from the Silurian upwards to the north of the great snowy axis of the Himalaya. His numerous papers on these subjects, dating from the year 1847, are published in the journals of the Royal Asiatic, Geological, and Royal Geographical Societies' Proceedings, and in the reports of the British Association."

THE POPULARIZATION OF SCIENCE

Discovery, a monthly magazine devoted to the popularization of science, initiated a year ago by Mr. John W. Harding, has been merged with The Popular Science Monthly. It is to be regretted that the financial conditions last year proved to be unfavorable to the support of a new journal of this character, planned to be both accurate and interesting. No one would suppose it possible to maintain a museum by the admission fees, but it is regarded as a matter of course

Photograph by Elliot and Fry

SIR RICHARD STRACHEY.

that a scientific journal should be supported by the subscribers. Yet there is reason to believe that a good popular scientific journal would accomplish as much for the instruction and entertainment of the public as one of our leading museums, whereas the cost of conducting a museum for a single year would give the journal an ample permanent endowment. But it is by no means certain that it would be an advantage for our scientific journals to be supported by endowments or subsidies. A public spirited and enlightened individualism, which would lead people in large numbers to subscribe to journals of educational value, to pay the entrance fees to museums and for tickets to scientific lectures, would in some ways be more satisfactory than the amplest endowments. Valparaiso University and Harvard University, Mr. Edison's laboratory and the Carnegie Institution, stand for diverse methods of solving problems of momentous importance. It may be that Valparaiso University and Mr. Edison's laboratory are the more nearly in touch with a true and vigorous democracy.

Perhaps some subscribers to *Discovery* who receive The Popular Science Monthly in its place will think that the Monthly is not entitled to use the adjective "popular." The publishers receive frequent postcards asking for a sample "coppy." This may be the better way to spell the word, but those unsophisticated by conventional orthography would probably not find the Monthly suited to their purposes. It is popular in the sense that it is not special or technical, not in the sense that it makes an appeal to all the people. We need a journal such as The Popular Science Monthly intended for those having a cultivated and intelligent interest in the advancement of science, but we also need a magazine for the larger class who visit museums and read the daily papers. Provision is now made for invention and technological science, but we should welcome the establishment and support of a magazine devoted to natural history and the simpler aspects of physical science.

SCIENTIFIC ITEMS

At the commenoration day exercises of Johns Hopkins University, on February 22, a portrait of Henry Newell Martin, formerly professor of biology, was presented to the university by his old students. The presentation speech was made by Dr. William H. Howell, dean of the medical school.

The Silliman lectures at Yale University will next year be given by Dr. Albrecht Penck, professor of geography at the University of Berlin.

The Bruce gold medal of the Astronomical Society of the Pacific has been awarded to Professor Edward C. Pickering, director of Harvard College Observatory.—The gold medal of the Royal Astronomical Society has been awarded to Sir David Gill. M. Henri Poincaré, the eminent mathematician, has been elected a member of the French Academy, in the place of the late M. Berthelot.

By the will of the late Mrs. Frederick Sheldon, Harvard University receives $300,000 for the enlargement of the library building or such other purpose as may be preferred, and the residue of the estate for establishing traveling scholarships. The total bequest will probably amount to more than $800,000.

THE POPULAR SCIENCE MONTHLY

MAY, 1908

SOME NEW VIEW POINTS IN NUTRITION[1]

BY PROFESSOR RUSSELL H. CHITTENDEN

SHEFFIELD SCIENTIFIC SCHOOL OF YALE UNIVERSITY

IN the latter part of the seventeenth century, long prior to the discovery of oxygen, the English chemist, John Mayow, had laid hold of the important principle that there is something in the air necessary for combustion; that this something is capable of exerting its influence whether it exists free in the air or is combined in the substance undergoing combustion. Further, he pointed out that in the processes of burning and breathing there is a certain definite relationship in that both consist in the consumption of the so-called igneo-aerial particles of the air. He made clear by experiment that the views then prevailing regarding respiration, in which it was held that breathing serves to cool the heat of the heart or to facilitate the passage of the blood from the right to the left side of the heart were quite erroneous. He maintained that in breathing, something belonging to the air, something essential for sustaining life passes from the air into the blood. To quote from his own statement:[2] "On the one hand it clearly appears that animals exhaust the air of certain vital particles which are of an elastic nature. On the other hand there can not be the slightest doubt but that some constituent of the air absolutely necessary to life enters into the blood in the act of breathing."

We fully understand to-day that Mayow's igneo-aerial particles were what we call oxygen, and that in some mysterious fashion he had

[1] An address before the Sigma Xi societies of the universities of Missouri, Kansas, Nebraska, Iowa and Minnesota, February, 1908.

[2] Taken from Sir Michael Foster's "Lectures on the History of Physiology during the Sixteenth, Seventeenth and Eighteenth Centuries," Cambridge University Press, 1901, p. 194.

arrived at a fairly accurate conception of the important part played by these particles in the processes of life. He recognized that the substance embodied in these particles "formed only a part of the atmosphere, that it was essential for burning, that it was essential for all the chemical changes on which life depends, that it was absorbed into the blood from the lungs, carried by the blood to the tissues, and in the tissues was the pivot, the essential factor of the chemical changes by which the vital activities of this or that tissue are manifested. It was essential in muscle to the occurrence of muscular contractions, it was essential in the brain to the development of animal spirits. This great truth was reached at a time when the men of chemistry were struggling with the spiritualistic fermentations of van Helmont on the one hand, and with the material effervescences of Sylvius on the other. It was reached by a young man of twenty-five years, who died a few years afterwards."[3]

For nearly a hundred years this fundamental idea so skillfully worked out lay practically dormant and no material progress was made until, in the latter part of the eighteenth century, Priestley prepared his dephlogisticated air and Lavoisier discovered oxygen. Then came essentially a revival of Mayow's views concerning respiration, only with a clearer understanding of the nature of the process. As stated by Lavoisier and Laplace, "respiration is a combustion, slow it is true, but otherwise perfectly similar to the combustion of charcoal. It takes place in the interior of the lung without giving rise to sensible light because the matter of the fire (the caloric) as soon as it is set free, is forthwith absorbed by the humidity of these organs. The heat developed by this combustion is communicated to the blood which is traversing the lungs and from the lungs is distributed over the whole animal system."[4]

In this conception of so-called respiration the fundamental errors as viewed from the standpoint of to-day are first: the idea that the process deals solely with the combustion of carbon and secondly, that the process is limited to the lungs where a hydrocarbonous fluid was supposed to be secreted, *i. e.*, from or through the tubes of the lungs. Later, Lavoisier himself recognized that in this process of combustion in the animal body hydrogen (discovered by Cavendish in 1781) was likewise involved, and that water as well as carbon dioxide was a normal product of the oxidation that is associated with respiration. Still later, the Italian investigator, Spallanzani, through his experiments on animals broadened the conceptions then prevailing by proving that the individual tissues of the body, like the organism as a whole, respire, *i. e.*, that they consume oxygen and produce carbon dioxide. This

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[3] Quoted from Sir Michael Foster, *loc. cit.*, p. 198.

[4] *Ibid.*, p. 249.

view, however, was slow in gaining ground, and for years it was generally held that oxidation as it occurs in the animal body takes place mainly in the lungs. Not until 1837 when Magnus, through use of the air pump, showed conclusively that both arterial and venous blood contain the two gases oxygen and carbon dioxide, though in different proportions, did the theory of respiration and its connection with oxidation take on its present form. Then, gradually, physiologists began to perceive that pulmonary or external respiration had to do primarily with the exchange of gaseous materials and that oxidation did not occur in the lungs, neither to any degree in the circulating blood, but rather in the different tissues and organs of the body where activity of various sorts prevails.

The processes of life, the processes of nutrition, soon came to be looked upon as essentially processes of oxidation. The work of Lavoisier in 1780, indicating as it did that animal heat is the result of a process of slow combustion in which oxygen is used up and carbon dioxide produced, a process analogous to that of the burning candle, naturally emphasized the idea of oxidation. As to the nature of the substance or substances undergoing combustion in the animal body, knowledge at that time was somewhat vague and indefinite. Later, when Chevreul had made his classical studies of fats and Mulder had essayed a description of protein, Liebig came forward with his theories of nutrition, among which was the view so long upheld, that the fats and carbohydrates of the food are burned up directly by the inspired oxygen, while the protein is used to replace the protein of the tissues, the latter being oxidized to furnish energy for muscle work. Liebig conceived that oxygen was the *cause* of oxidation, a view shown to be incorrect by the well-established fact that animals produce no more carbon dioxide in an atmosphere rich in oxygen than under ordinary atmospheric conditions, *i. e.*, unlike the processes of combustion outside the organism a forced draft is without effect on the rate of burning. Moreover, it was found that oxidation would take place in a tissue independent of an intake of free oxygen, viz., that a contracting muscle, for example, would give out carbon dioxide even when made to contract in a vacuum, thus implying a decomposition or disassociation in which combined oxygen must have been made use of. Further, it was evident that in the tissues and organs of the body, oxidation proceeded gradually through a series of successive steps; the large, complex molecules of the food and tissues being slowly transformed into simpler molecules with ultimate formation of carbon dioxide and water, plus some nitrogen-containing compounds of a relatively simple nature.

During all these years, since the time of Mayow and the later discovery of oxygen, oxidation has been the key-note to which all the varied changes characteristic of life have been adjusted. In ultimate analysis, the breaking down of tissue material in the complicated processes of catabolism has been ascribed to oxidation. While this explanation is in a measure true, the passing years have brought to light many additional data which tend to show that simple oxidation is quite inadequate to account for the variety of transformations that pertain to nutrition. Many other factors are involved that give to these processes a totally different and at the same time broader scope than was formerly thought of. The simple views of Lavoisier and the later theories of Liebig do not suffice; they fail to explain the numerous and complicated reactions occurring during life.

Something was lacking in our knowledge during these earlier years, and that was an understanding of the rôle of the cell in nutrition. It was difficult for the chemists of this period to let go of the tempting hypothesis that oxidation in the animal body was akin to that of ordinary combustion and their eyes were apparently closed to the many inconsistencies that such a theory imposed. When, however, Virchow developed his cellular hypothesis and it became clear that the living cell was the morphological unit of the body, then it gradually dawned on the physiological world that the cell was likewise the seat of the many chemical transformations associated with nutrition. Oxidation could not occur in the lungs, it did not take place in the blood, there was no one particular spot where the fires of the body were located. On the contrary, they occurred everywhere, in every living cell, and all kinds of combustible or oxidizable material were burned. This conception, in which the living cells might well be compared to miniature laboratories, is now thoroughly justified by the facts at our disposal. Still, it is not the cell as a physiological unit that is to be considered as the cause of the varied decompositions that occur in the body. Enzymes of various types appear in the foreground whenever we attempt to unravel the nature of the processes associated with nutrition; and this is equally true whether we are dealing with the changes incidental to digestion or with those more subtle ones associated with the processes of metabolism. In the living cells of the body there are many agencies at command, enzymes or ferments of divergent forms endowed with the power of inciting and carrying forward chemical changes of differing degrees of magnitude, by means of which complex organic matter is made to undergo alteration and decomposition.

Turn for a time to the changes which the protein or albuminous foods undergo in digestion. Here we have what was for a long period considered as a simple process of transformation or polymerization, brought about mainly through the agency of the two enzymes pepsin and trypsin, of the gastric and pancreatic juice, respectively. Physiologists for years believed they understood the purport of this process, which was merely to transform the protein foods into soluble and more or less diffusible modifications adapted for absorption into the circulating blood. The various forms of vegetable and animal proteins supposedly underwent transmutation without much chemical change, into closely allied substances which by simple osmosis or diffusion could enter the circulation and thus be distributed throughout the body. We see in these views a striking example of how preconceived ideas stand in the way of progress. Advance of knowledge is frequently held back by our proneness to interpret observations or data in harmony with our conception of what they should signify. The old-time physiologists knew full well that the protein of the blood and tissues was made good by the protein of the food, and digestion as they understood it was adequate for the purpose, viz., to transform the protein into a soluble and diffusible form. Anything beyond this was not only unnecessary, but uneconomical and wasteful. I well remember an experience of my own twenty-five years ago in Germany when I was at work on the so-called primary and secondary proteoses formed in gastric digestion, substances at that time just discovered as products of digestive action; how an eminent physiologist from Dorpat happened in the laboratory one day, and after looking at some of the products he turned to Kühne, who was standing near-by and remarked, "It is certainly interesting to see what changes pepsin is capable of producing, but of course they have little bearing on the processes that take place in the stomach and intestine, where naturally the sole aim is to fit protein for absorption."

Another eminent physiologist, whose name has long been known to every student of the science, remarked once in my hearing that the acid-albumin stage, the first product formed by pepsin-acid, was as far as gastric digestion need extend, since this substance was easily absorbed and it was a useless waste of energy for protein to undergo conversion into primary and secondary proteoses and peptone. I recall also what controversies arose when it was established that artificial pancreatic juice could break down protein into leucine and tyrosine; those two crystalline amino-acids now so well known as decomposition products of most proteins. When the fact was established beyond a shadow of doubt, physiologists were still disinclined to believe that any appreciable amount of these relatively simple substances could be formed in ordinary digestion, because such a view was so strongly opposed to the general purpose of protein digestion as then held. We were not inclined to follow the path which experiment was opening up simply because our eyes were blinded by preconceived ideas. I recall an early experiment made by Kühne and myself in the Heidelberg laboratory where a dog was fed a large amount of meat and then after a suitable time chloroformed, the small intestine ligatured and the contents analyzed. We found a gram or more of leucine and tyrosine, which we weighed and identified, thus proving to our satisfaction at least that these two amino-acids were formed in ordinary intestinal digestion. But such data twenty-five years ago, and indeed up to very recent times, failed to attract much attention or were misinterpreted. Physiologists hastened to formulate a theory which would harmonize with existing views, and so arose the theory of "luxus consumption," in which it was held that when an excess of protein food was taken, far larger than the demands of the body called for, the organism was able to protect itself by virtue of this power possessed by trypsin of breaking down protein matter into simple decomposition products easily got rid of with less strain upon liver, kidneys and other organs and tissues.

Many of you doubtless remember the experiments of Schmidt-Mülheim and of Fano, who attempted to determine the amounts of proteoses and peptones present in the blood of dogs after a hearty meal of protein food; and how the negative results they obtained led finally to experiments on the injection of these substances directly into the blood, in which it was found that marked physiological action followed. In other words, proteoses and peptones are not normal constituents of the blood, even though there be a large amount of them in the intestine. They are plainly not absorbed as such, and this fact led to the theory—apparently supported by experiment—that proteoses and peptones in the very act of absorption, in their passage through the epithelial cells of the intestinal wall, are transformed into the proteins of the blood. This made a convenient way of explaining the facts, and one could well imagine that the system took this method of reinforcing the proteins of blood, lymph and tissue. Data, however, have been slowly accumulating which do not admit of such easy interpretation. Physiological chemists interested in enzyme action and equally interested in the chemical constitution of protein matter have been gradually collecting evidence of much significance. A row of diamino-acids, arginine, lysine and histidine, together with alanine, proline, cystine, tryptophane, etc., have been discovered as hydrolytic decomposition products of proteins, both by the action of pancreatic juice and by boiling dilute acids, in addition to the earlier known leucine, tyrosine, glycocoll, aspartic and glutaminic acids, etc. Further, it has been shown that pancreatic juice in artificial digestion experiments, if sufficient time be allowed, is able to bring about a complete breaking down of the protein molecule into these relatively simple amino-acids, so that the biuret reaction, for example, entirely disappears. For a time, this extremely significant fact was not accredited with much importance physiologically; it was interesting; it testified to the general lability of the protein molecule and it threw light on the nature of the building stones which make up the protein complex. Then came, as many of you know, the comparatively recent discovery by Cohnheim of the enzyme erepsin in the duodenal mucous membrane; an enzyme which acts especially on secondary proteoses and peptone, breaking them down quickly into amino-acids. This enzyme is naturally present in the intestinal secretions, becomes mixed with pancreatic juice, and is able to reinforce the latter in the complete destruction of the food proteins in the intestine, the final products being simple amino-acids and their combinations known as polypeptides.

Now, we understand why proteoses and peptone are not normally present in the circulating blood, even of the portal vein. We see that it is no longer necessary to assume a construction of blood proteins from absorbed proteoses and peptone. The old dictum, so often quoted, that the proteins of our muscle tissue, for example, are simple transformation products of the various food proteins no longer satisfies us, since it is so out of harmony with observed facts. We see opening up before us a totally different conception of the process of digestion so far at least as it relates to protein food. It has been a long period of time since the discovery of the proteolytic enzyme of the gastric juice by Schwann, or the early work by Claude Bernard on pancreatic juice. Slowly, but surely, however, our knowledge has progressed, until to-day we are on the threshold of a new vista; new paths spread out before us filled with the light of truth and they bid us hasten to clear away the accumulated misconceptions of the preceding years.

Think for a moment what the new facts lead to in their bearing on nutrition! Recall how we have come to understand that the specific immunities and specific reactions of the blood of different species are properties which reside in the individual blood proteins, and that these peculiarities are associated with the chemical constitution of the proteins. Every physiologist knows how greatly blood from different species varies, and we may safely say that each species of animal probably possesses blood characterized by a personal coefficient in the constitution of its proteins, upon which rests in some measure at least its physiological individuality. In the light of such suggestions is it not difficult to conceive of the varying food proteins of our daily diet being merged into the specific proteins of blood and tissue through simple transformation into closely related proteoses and peptones? Can their individuality be so easily lost by such a superficial alteration? No, the facts at our disposal to-day clearly indicate that the proteins taken as food can not find a place in the economy of the animal body until (as aptly expressed by Leathes) they have been, as it were, melted down and recast. Stated in different language, it is apparently the purpose of digestion, through the enzymes, pepsin, trypsin and erepsin, to thoroughly dismember the protein molecule so that no vestige of its original structure remains; while out of the many fragments or chemical groups so split apart the body can reconstruct proteins adapted to its own particular needs. This means synthesis of a most marked kind, quite different in character from that implied by the hypothetical transformation of absorbed proteoses and peptone in the mucous membrane of the intestine. Further, there is suggested a far-reaching application of this synthetical power in the construction of tissue protein throughout the body.

Let us grant that in the intestinal walls or elsewhere the serum albumin and globulin of the blood are constructed *de novo* from the many simple fragments split off during the processes of digestion, what then is the origin of the many different forms of protein, nucleoprotein, etc., which characterize the various tissues and organs of the animal body? Do these result from simple transformation of the blood proteins which, as we are wont to say, nourish the active cells of the body and serve as pabulum for the hungry tissues?

> No account has been commonly taken of the fact that these proteins of the blood must be taken to pieces and again put together, rearranged on a different plan, if they are to serve for the making of proteins and nucleoproteins in the cells of the muscles and other organs in which the destructive changes of life are felt. The proteins circulating in the blood are a currency which is not legal tender. And no account has been commonly taken of the familiar fact that when no food is obtainable, certain organs maintain for themselves a normal composition at the expense of the substance of other organs. When the spleen, liver, or the muscles of the limbs dissolve away in starvation, the heart feeds on what they supply. Are the proteins of these organs converted into serum albumin and globulin, or are they melted down by autolytic processes into the same cleavage products as are formed in the digestion of food, and in this form thrown into the circulating blood, which is thus in a position to supply the heart and diaphragm with just what they are accustomed to receive in the blood from the digestive organs? (Leathes.)

In attempting to answer this question, I need only call to your attention the many data collected during the past few years concerning autolysis in general; in which it has been found that practically all the organs of the body are capable under suitable conditions of undergoing auto-digestion, with formation of essentially the same cleavage products as result from the breaking down of proteins in the gastro-intestinal tract. Further, the ferments or enzymes that are responsible for these autolytic transformations have been in some measure isolated and separated from each other. When these facts were first brought to light, it was assumed that the changes in question were mainly at least the result of post-mortem conditions, but there is no justification for such an assumption. Intracellular enzymes are a part of the natural equipment of living cells, and metabolic events, nutritional changes, such as characterize the life and activity of tissues and organs in general, are undoubtedly due to the power of these agents, normally controlled, however, by a variety of conditions that must tend to balance conflicting interests. We can well imagine that in the life and death of tissue cells autolytic decompositions are constantly taking place whereby cell protein is broken down into its component parts, while at the same time a synthesis of protein may be occurring from other amino-acids brought by blood or lymph with a possible utilization of some of the fragments liberated by the autolysis. In other words, our conception of nutritional changes to-day embodies the hypothesis of a synthesis of protein throughout the body; that it is a function of every living cell, "each one for itself, and that the material out of which all proteins in the body are made is not protein in any form, but the fragments derived from proteins by hydrolysis, probably the amino-acids, which in different combinations and different proportions are found in all proteins, and into which they are all resolved by the processes, autolytic or digestive, which can be carried out in every cell of the body" (Leathes).

Here, we have presented several points of view which are radically unlike the old-time traditions concerning nutrition. Objects and methods are both out of harmony with the long prevalent conception of the plan of the living organism in which oxidation was confessedly the ruling power. Profound and progressive hydrolytic cleavage is now seen to be the purpose of digestion, as well as of the autolytic processes which are associated with all the tissues and organs of the body; a cleavage which proceeds until the complex protein is split apart into its simplest chemical groups or components. In this process there is no sign of direct oxidation, but hydrolysis appears in the foreground, and by this means the rock protein is broken asunder into small fragments of definite shape, each of which can be used in the construction of fresh protein. Especially noteworthy is the harmony of action between the enzymes of the digestive tract and those of the living tissues of the body. Both have the same object in view; there may be differences in the rate of action, but in the end essentially the same simple fragments result. Again, what a suggestion of broad constructive power in the cells of the animal body; what a powerful synthetical process that by which the animal cell manufactures the most complex substance of its body protoplasm! For years the chlorophyll-containing cell of the plant world enjoyed the distinction of being the main laboratory in nature for the synthesis of organic compounds. The animal body could transform and modify, it could even accomplish a mild form of synthesis, such as a combination of two large molecules to form a still larger conjugate, but anything like a true synthesis, *i. e.*, the formation of a well-defined complex, such as protein, out of simple amino-acids was far beyond our imagination, until now accumulated facts seem to open up a new point of view.

Are we really warranted in accepting this modern conception of protein synthesis in the animal body? Are the facts available sufficient to substantiate the claim advanced? Physiologists quickly recognized the necessity of confirmatory evidence on this important matter, for a hypothesis so far-reaching in its significance demands careful consideration before it can be given much credence. We understand full well that protein is an essential foodstuff, without which life can not be maintained. We have been accustomed to consider that no other form of nitrogen than protein-nitrogen can supply the physiological needs of the body. If, however, it is true that in normal digestion the protein molecule is completely broken down into relatively simple fragments, non-protein in nature, *i. e.,* into amino-acids and polypeptides, and that from these fragments specific proteins are reconstructed, then it is plain that animals fed on a diet free from protein, but with a proper amount of these nitrogenous cleavage products, should live and thrive, assuming, of course, a sufficient addition of non-nitrogenous food. Experiments after this order have been tried by various investigators, with very interesting results. Dogs, for example, fed on a mixture of protein cleavage products with suitable addition of fat and carbohydrate, maintained nitrogen equilibrium and even stored up nitrogen, presumably in the form of protein, thus indicating that the animals were able to utilize these end products of protein decomposition in much the same way as protein food would be utilized. The only logical supposition is that the dogs were able to manufacture body protein out of this composite of protein fragments; *i. e.,* a synthesis of protein took place; otherwise it would have been impossible to maintain a condition of nitrogenous equilibrium even for a day. Similarly, white rats gained in weight and stored up nitrogen on a diet in which the protein of their food was entirely replaced by the digestion products formed by trypsin and erepsin. Abderhalden and Rona,[5] using a dog as subject and feeding the products formed by pancreatic digestion of casein, viz., the amino-acids and other biuret-free products, found it possible to prevent completely the loss of body protein, a further proof of the power of the animal organism to synthesize protein from its final cleavage products.

Experimental evidence of this character forces us, whatever our preconceived notions, to admit the power of the animal body to build up its needed protein out of the relatively simple decomposition products into which the various forms of food protein are broken down by the processes of digestion. Oxidation does not appear—on the surface, at least—but progressive hydrolytic cleavage is the key-note. The food protein, like a crystalline geode, is split apart into numerous crystalline fragments by action of the several digestive enzymes to which it is exposed in the gastro-intestinal tract, and from these fragments the body cells apparently select such as are required to construct the specific proteins needed for the replacement of those used up in the processes of life. The hydrolytic cleavage induced by these digestive

[5] *Zeitschrift f. physiologischen Chemie,* Band 44, p. 200.

enzymes is, however, in some measure peculiar, in that the fragments are not wholly akin to those formed by hydrolysis with acids. When a given protein is boiled with a dilute acid it is speedily broken down and many of the fragments are identical with those produced by the action of trypsin and erepsin. Thus tyrosine, leucine, arginine, lysine, histidine, etc., appear in both cases, but the enzymes presumably leave intact certain groups or combinations which acids break up or in some way modify. As a result, it is found that the cleavage products formed from casein, for example, by acids, will not take the place of casein, or the products formed by trypsin proteolysis, in meeting the needs of the body. On a diet of protein cleavage products formed in this manner the animal steadily loses nitrogen; it is impossible to maintain a condition of nitrogenous equilibrium, since for some reason the tissue cells can not synthesize protein from the mixture of fragments produced by acids. We may conjecture that while in acid hydrolysis the products are all simple amino-acids, in enzymolysis combinations of the amino-acids, *i. e.*, polypeptides, remain intact. There is experimental evidence that such is actually the case, but equally good evidence seems to show that the presence of polypeptides is not essential for the synthesis of protein by the animal body. Thus, Henriques and Hansen found that by treating the mixed products of pancreatic digestion with phosphotungstic acid, which precipitates, so far as at present known, all the basic bodies including polypeptides, the mixture of monoamino-acids and possibly other nitrogenous substances contained in the filtrate is apparently able when fed to keep animals in a condition of nitrogen equilibrium. Further, the same investigators found, on treating the nitrogenous products (free from biuret reaction) of pancreatic digestion with strong alcohol, thereby separating the substances into two portions, the alcohol-soluble part was quite able to maintain animals in nitrogen equilibrium, *i. e.*, it was equivalent in action to the original protein, while the portion insoluble in alcohol was wholly ineffective. It is thus apparent that all of the fragments resulting from proteolysis are not needed for the synthesis of protein; there are apparently certain products that are not essential or not immediately necessary. On the other hand, it is equally apparent that in the more profound breaking down of proteins by acids, something is done which constitutes a physiological obstacle to utilization of the products in the synthesis of protein by the animal body.

As stated by Leathes:[6]

> The great bulk of the substances set free in the hydrolysis of proteids by enzymes and by acids are the same, and these substances enter into the composition of the proteids synthesized in the body in similar proportions to those in which they occur in the proteids of the food. For the present, all we can

[6] "Problems in Animal Metabolism," 1906, p. 132.

say is that there appears to be some kind of linkage between certain groups in the proteid molecules which is not uncoupled by the enzymes in the body, and that when it is uncoupled, as in acid hydrolysis, then it is impossible for it to be coupled up again in the body. This combination, which the cells can neither take to pieces nor put together again, must be present, in order that the other component parts of the proteid molecule may gather about them and group themselves round them when the synthesis of proteids is to occur. These considerations appear to suggest that the synthetic processes here involved may be the work of the same agent as the hydrolytic, the limitations in its hydrolytic power determining the limitations of its synthetic activity, as in reversible zymolysis.

Whether this conception of the matter is wholly correct we can not say, but at all events it is a suggestion as plausible as any that can be offered at the present time.

Just here we may advantageously consider the nature and proportion of the chemical components present in the protein molecule so far as has been ascertained by hydrolysis with acids. Recently, much work has been done on this subject, especially by Dr. Thomas B. Osborne at New Haven. The accompanying table gives the results with eight typical proteins from the animal and vegetable kingdoms, which may be taken as representative of the present state of knowledge.

Percentage Yield of Cleavage Products

	Gelatin[7] Bone	Casein[8] Milk	Excelsin Brazilnut	Hordein Barley	Phaseolin Bean	Gliadin Wheat	Glutenin Wheat	Leucosin Wheat
Glycocoll	16.5	0	0.60	0	0.55	0	0.89	0.94
Alanine	0.8	0.9	2.33	0.43	1.80	2.00	4.65	4.45
Valine	1.0	1.0	1.51	0.13	1.04	0.21	0.24	0.18
Leucine	2.1	10.5	8.70	5.67	9.65	5.61	5.95	11.34
Proline	5.2	3.1	3.65	13.73	2.77	7.06	4.23	3.18
Phenylalanine	0.4	3.2	3.55	5.03	3.25	2.35	1.97	3.83
Aspartic acid	0.56	1.2	3.85	+	5.24	0.58	0.91	3.35
Glutaminic acid	0.88	11.0	12.94	36.35	14.54	37.33	23.42	6.73
Serine	0.4	0.23	0	......	0.38	0.13	0.74	......
Tyrosine	0	4.5	3.03	1.67	2.18	1.20	4.25	3.34
Arginine	7.62	4.84	16.02	2.16	4.89	3.16	4.72	5.94
Histidine	0.40	2.59	1.47	1.28	1.97	0.61	1.76	2.83
Lysine	2.75	5.80	1.64	0	3.92	0	1.92	2.75
Ammonia	......	......	1.80	4.87	2.06	5.11	4.01	1.41
Tryptophane	0	1.5	+	+	+	+	+	+
Cystine	......	0.06	0	+	......	0.45	0.02	......
	38.61	50.42	61.09	71.32	54.27	65.80	59.68	50.27

All the above data from vegetable proteins were furnished by Dr. Thomas B. Osborne and represent his own work and that of his co-workers.

Perhaps the most impressive fact, certainly the one most quickly discernible, is that a large fraction of the protein molecule, 28–50

[7] Emil Fischer, P. A. Levene and R. H. Aders.

[8] Abderhalden. Cow's milk.

per cent., is of unknown composition. It is not unaltered protein, of that we can be sure, because all protein is destroyed in the hydrolysis. It is presumably composed of small fragments of some kind, not yet recognized by chemists. The next most noticeable feature is that no two of these proteins are alike in their chemical make-up. Proteins from the same grain are distinctly unlike; gliadin of wheat contains no lysine, while leucosin from the same kernel contains 2.75 per cent. of this basic substance; gliadin likewise contains 37 per cent. of glutaminic acid, while leucosin has less than 7 per cent.; gliadin shows 5.6 per cent. of leucine, and leucosin twice that amount; gliadin contains no glycocoll, while leucosin has nearly 1 per cent. of this amino-acid. Such marked differences in chemical composition speak plainly regarding the individuality of proteins, even of those which are associated in the same seed. Comparison of casein from cow's milk, as a typical animal product, with any of the vegetable proteins, brings to light equally strong points of difference, while in gelatin we see many of the familiar amino-acids reduced to a minimum or entirely lacking. While it is undoubtedly true that all proteins possess certain features in common, it is becoming strikingly manifest that they are more or less divergent in chemical constitution. It has been the custom of physiologists in the past to lay stress upon the general rule that proteins are substances capable of meeting the physiological necessities of the body and that their nitrogen exists in a form suited to the needs of the organism. We have been accustomed to point to gelatin as the one exception to the rule, and have classed it as a protein-like substance, with as much nitrogen or even more than most proteins, but not truly a protein, since it can not support life. I fancy, however, that many true proteins may prove, when taken alone, unable to support life. As a matter of fact, few isolated proteins have been tested in this respect. Most of our feeding experiments have been made with mixtures of proteins, and consequently a considerable variety of protein cleavage products have been available for nutritive purposes. Take, as an illustration, the zein of corn meal, which contains no tryptophane, glycocoll nor lysine whatever, and only 1.5 per cent. of arginine and histidine combined, but with 18.6 per cent. of leucine, to say nothing of other peculiarities of chemical structure. Is it not reasonable to suppose that such a protein, with so many of the ordinary chemical groups missing or in greatly diminished quantity, will prove inadequate to meet the demands of protein synthesis? Experiment with animals has, indeed, shown this to be the case.

Data along these lines are bound to bring us more definite information than we at present possess regarding the real merits of vegetarianism as contrasted with the use of animal foods. At present, so-called vegetarianism rests mainly upon sentiment, reinforced by the belief that the quantitative needs of the body for protein food are more satisfactorily met by a liberal addition of vegetable matter with its larger calorific or heat-producing power and smaller nitrogen content. In view, however, of what has been stated concerning the divergent chemical structure of individual proteins, it is obvious that a new standard of comparison is at hand, the suggestions it may offer to be tested by appropriate feeding experiments on man and animals. Truly, no chapter of nutrition is more deserving of careful consideration, both from a scientific standpoint and from its bearing on the welfare of the human race, than that which deals with the relative capabilities of the various proteins of animal and vegetable origin.

In all that has been said we see emphasized the ability of the living organism to break down its complex food material, as well as the corresponding material of its tissues and organs, into the simplest of chemical fragments, coupled with the capacity to construct equally complex tissue material out of the fragments so produced. Profound and progressive hydrolysis, rather than simple oxidation, is the method of decomposition, for many of the fragments at least are to be carefully conserved for future use. Oxygen, however, may play its part in connection with the smaller groups, though even here enzyme intermediation may still be found a ruling factor. Enzymes are to be detected on all sides, both inside and outside the cells of the individual tissues and organs, and it is through their agency that the varied processes of life are carried forward. The present realization of the profound part played by enzymes in the reactions of the animal body is completely transforming our views of life. The so-called vital activities of living tissue or its component cells are no longer shrouded in that mystery which defies explanation, but we see within our reach tangible means of unraveling the complexities of cellular activity. One by one, the old views of living matter and organic structure are giving place to truly scientific conceptions that admit of logical interpretation. It is not long since, when chemists and physiologists alike viewed with enthusiasm, akin to awe, the production of an organic compound by synthesis in the laboratory. I well remember meeting the renowned Wöhler, then an old man, in one of my early visits to Göttingen. Yet, Wöhler was the first to make an organic substance by synthesis. Up to his time, physiologists all believed that organic substances, whether simple or complex, could be formed only through the agency of a living organism. To-day, however, there is almost no limit to our power of producing organic substances by purely chemical synthesis. In the hands of the chemist, many of the reactions of living matter may be duplicated and we are led to see that the living organism makes use of processes which are merely a counterpart of those we have learned to control in the laboratory.

When Buchner a few years ago, by simple pressure, forced from the yeast cell a little limpid fluid and with this was able to induce the same chemical reactions that the living yeast plant produces when brought in contact with a sugar solution, it became clear that the typical formation of alcohol and carbon dioxide is not the result of the *life* of the yeast plant as formerly supposed, but is instead to be attributed to something—a chemical substance—easily separable from the yeast cell, and quite capable of causing the fermentation of sugar. This reaction, which had for so long been looked upon as a typical illustration of the power of life in inducing chemical change, is merely a simple process of enzymolysis. The yeast plant, it is true, produces the enzyme; but the isolated ferment, once formed, is just as capable of decomposing the sugar as the yeast plant itself. Indeed, the latter is able to accomplish this chemical reaction, solely because of the presence of the enzyme or ferment, now called zymase. In all forms of animal and vegetable tissue, intra- and extra-cellular enzymes abound; enzymes of varied nature, endowed with the power of inducing chemical reactions of diversified character. Those previously referred to in the breaking down of protein material, both in digestion and in autolysis, are typical of what may be found in many of the fluids and in most of the tissues of living organisms. Enzymes which induce hydrolytic cleavage are especially abundant; sugars, proteins and fats all falling as prey to their power of breaking down the respective molecules into smaller and simpler ones better fitted for distribution or utilization. Further, enzymes of the amidase type, which have the power of removing nitrogen from nitrogenous compounds, are equally conspicuous in many phases of intermediary metabolism, especially where changes of nuclein material are involved. In this reaction the elements of water are apparently alone involved, but in some mysterious fashion the enzyme causes a retention of oxygen while the hydrogen passes off with one atom of nitrogen in the form of ammonia, thus leading to the formation of a new substance with one more atom of oxygen than the body from which it was formed and with one less atom of nitrogen and of hydrogen. In this way, gradual oxidation results without free oxygen being involved, while at the same time the content of nitrogen is reduced. Again, there are enzymes separable from the tissues of the body which bring about the destruction of uric acid, not, however, by a process of annihilation, as might be implied by the above statement, but by a method of cleavage in which new bodies less complex are formed. Equally manifest is the action of enzymes which bring about glycolysis, *i. e.*, the destruction of sugar as in the blood; while the separation of the amido group from amino-acids, the oxidation of aromatic aldehydes, the splitting apart of a substance like arginine into urea and ornithine, and a host of kindred reactions, all testify to the multitude of chemical changes that the enzymes of the animal body are capable of producing.

Turn for a moment to the oxidation of an amino-acid such as leucine, which is well known as a product of pancreatic digestion. As this process is carried out in the body under the influence of specific enzymes it is quite different from the ordinary conception of oxidation or combustion. Instead of a complete destruction of the molecule, there is first a removal of ammonia and of carbon dioxide, followed by the formation of an aldehyde and an acid free from nitrogen, together with acetone. The same kind of a reaction can be induced outside the body by some mild form of oxidation, as with hydrogen peroxide, as has recently been shown by Dakin. Here we have a series of reactions, in which an amino-acid by successive oxidation yields a row of non-nitrogenous substances such as are found in the intermediary metabolism of the body, *i. e.*, an aldehyde, an acid, and finally acetone, nitrogen being removed from the molecule in the early stage of the process. Such facts as these throw light upon the methods of oxidation as they occur in the living organism, and they teach us to understand that animal oxidation is quite different in character from the old-time conception of the process. The amount or volume of oxygen has no influence on the character of the change produced, but the specific enzyme exercises a controlling power by means of which a progressive, gradual change is induced leading to the formation of a row of kindred substances of more or less physiological significance.

In other words, the oxygen so freely drawn into the lungs at every inspiration is not directly responsible for the oxidations that take place in the body. Animal oxidation is a roundabout process, in which food and tissue material are first through the agency of numerous enzymes subjected to a variety of changes whereby easily oxidizable decomposition products are formed, which may eventually succumb to the influence of oxygen; even here, however, enzymes of the oxidase type may prove to be the controlling factor in determining whether or not oxidation results.

The "spontaneous combustion" of hay affords a striking example of the activity which oxidation of the organic foodstuffs may attain when decomposition of the latter has previously set in. If hay is stacked before it is thoroughly dry, decomposition begins in the middle of the damp stack through the action of organized or unorganized ferments. As all decomposition by ferments is accompanied by hydration, drying is the best means of preventing it. Heat is liberated by the decomposition, and proportionately with the rise in temperature in the middle of the stack an ever-increasing accumulation of easily oxidizable decomposition products is formed. If the hay be now disturbed so that there is free access of atmospheric oxygen to the internal parts of the stack, the whole blazes up and is consumed.[9]

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[9] Quoted from Bunge: "Text-book of Physiological and Pathological Chemistry," 2d edition, 1902, p. 252.

In the animal body, however, there is no such accumulation of decomposition products as is implied here, but the principle involved may possibly admit of application.

It is generally understood that muscular energy comes primarily from the decomposition or oxidation of non-nitrogenous material, either of the food or of the tissues; and in man we are accustomed to measure the amount of muscular work performed by the amount of oxygen consumed and the amount of carbon dioxide thrown out. In other words, the potential energy of the foodstuffs is made available through oxidation. This, however, is not always the case. Thus, in *Ascaris,* a round worm inhabiting the intestine of some of the higher animals, we have an animal that can live and show extremely active movements for days at a time without any appreciable amount of oxygen. Carbon dioxide is given off abundantly, however, thereby implying a cleavage or process of disintegration in which energy is freely liberated for the necessities of the animal's machinery. It is quite apparent, however, that oxidation is not the source of muscular energy in these organisms. It may be claimed, and perhaps justly, that such an illustration as this can not be applied legitimately to animals higher in the scale of life, yet there is experimental evidence from various sources pointing in the same direction. Thus, Stoklasa[10] has shown that organs from the higher animals, notably the lungs, liver, pancreas and muscle, yield on pressure fluids, from which by precipitation with alcohol and ether enzymes can be separated, having the power of producing in perfectly sterile solutions of sugar—and with exclusion of micro-organisms—alcoholic fermentation. The proportion of carbon dioxide and alcohol formed under these conditions is the same as produced by yeast. Remembering that in alcoholic fermentation sugar is simply split apart into alcohol and carbon dioxide, it is readily seen that the liberation of a certain amount of energy is possible by simple cleavage of the sugar molecule and without the intervention of oxygen. This then is a form of anaerobic metabolism or respiration, possibly analogous to that which occurs in *Ascaris,* where carbohydrates are broken down and energy set free for the needs of the organism. Again, Hermann years ago proved that a freshly excised muscle, from which all free oxygen had been separated by exposure to a vacuum, when placed in an oxygen-free medium could be made to work and give off carbon dioxide. Other data of a similar nature might be presented showing quite conclusively the power of animal tissues to carry on various decompositions of complex organic matter with an output of carbon dioxide and with consequent liberation of energy where free oxygen is entirely wanting. These are facts, however, well known to physiologists, but they serve to emphasize the validity of the present

[10] *Zentralblatt für Physiologie,* Band 17, p. 465.

point of view, viz., that the processes of animal metabolism are peculiar and are by no means always concomitant with ordinary oxidation. Outside the animal body, the customary components of our daily food, the proteins, fats and carbohydrates, are not affected by oxygen even at the body temperature or by long exposure to the gas. Catalytic action is a necessary prelude to their oxidation, and it is the smaller molecules resulting from the action of enzymes working through catalysis that are mainly burned up or broken down with liberation of their contained energy.

The processes of nutrition are truly complicated, and we can readily conjecture that their harmonious working is dependent in large measure upon the integrity of many closely related operations. Enzymes must be elaborated in due proportions, both in digestive secretions and in tissue cells; proper conditions for enzymolysis must prevail at the places where the reactions take place, since enzymes are extremely sensitive to their environment and fail to work unless all the requirements are fully met; proper conditions of circulation of blood and lymph must be maintained, in order to supply fresh pabulum and to prevent undue accumulation of the products of enzymolysis. In short, there are a multitude of accessory reactions to be preserved in their proper sequence and normal rhythm if perversions of nutrition are to be avoided. Many a substance known to have a deleterious effect upon nutrition does so in virtue of its action upon some one or more enzymes with which it may be brought in contact in the body. Take, for example, the well-known influence of alcohol as a factor in the causation of gout. In this disease, there is an increased amount of uric acid in the system, due in part to an inhibition of its oxidation and consequent destruction. When alcoholic fluids are taken, together with an excess of meat or kindred animal foods, the kidneys at once excrete increased amounts of uric acid, in harmony with the increased content in the blood. It is a well-known fact that alcohol interferes with the oxidative processes in the liver. It is equally well known to-day that the liver and other organs contain an enzyme, or more specifically an oxidase, which has the power of oxidizing uric acid to urea and other products. After the ingestion of alcohol and animal foods rich in uric acid precursors, the notable increase of uric acid in the blood and urine is considered as due to the inhibitory action of alcohol on this oxidase, which under normal conditions causes more or less destruction of uric acid. The failure of the enzyme to accomplish its ordinary duty naturally results in an accumulation of uric acid in the system, although the kidneys plainly endeavor to meet the new conditions by increased elimination. Hence, we see that the predisposition to the development of gout caused by the ingestion of a high protein diet reinforced by alcohol is to be explained in part at least by the direct influence of alcohol on this oxidizing ferment which is normally charged with the destruction of any surplus of this deleterious substance. Here we have a definite and logical explanation of an abnormal condition where interference with the routine action of a tissue ferment or enzyme is one of the specific causes of the disturbance.

This is one of many illustrations that might be cited showing how alterations in the environment of the enzymes occurring in the body may modify the rate of action, either by stimulation or inhibition, and thereby pave the way for marked disturbances of nutrition. It is easy to see also how the many enzymes which rule the normal nutritional processes of the body may need control in order to prevent undue activity, or excessive enzymolysis, with consequent disturbance of the normal nutritional rhythm. Nature has apparently provided this protection by a row of anti-bodies widely distributed which serve as specific antiferments, and either prevent undue alteration or check entirely the action of a given enzyme in certain localities where its action would be detrimental. We find illustrations of such antiferments in the gastro-intestinal tract, by the presence of which the digestive enzymes are restrained from attacking the proteins of the tissue cells, composing the lining membranes of the intestine. Apparently, there is no reason why the enzymes pepsin, trypsin, etc., which digest so vigorously the various protein foodstuffs should not attack with equal avidity the related proteins present in the mucous membranes of the stomach and small intestine. This, however, does not occur during life, no matter how strong the digestive fluids that are secreted into the digestive tract, partly at least because of the inhibitory effect of the natural anti-bodies that are present in the membranes. Again, it is interesting to note that just as antitoxins are produced in the animal body by the injection of a proper amount of toxin into the system, so likewise antiferments can be formed by injection subcutaneously of specific enzymes. Thus, as Morgenroth found, if the enzyme rennin which coagulates milk be injected under the skin of an animal in small doses, after a time the blood serum of the animal so treated will contain something which hinders or prevents the coagulation of milk. In other words, an anti-rennin is formed, just as under similar conditions an antitoxin may be produced. We thus see a close similarity or analogy between the production of a specific immunity toward a given toxin and the formation of antiferments.

Finally, we may again emphasize the specific character of the many ferments that play such an important part in the nutritional processes of man and the higher animals. We readily understand that an enzyme capable of acting upon proteins is quite ineffective when brought in contact with a carbohydrate, or that an enzyme able to digest one form of sugar can not attack even a closely related sugar belonging to the same group. The specificity of enzymes, however, extends farther than this, being intimately connected with the chemical configuration of the molecule acted upon. As a rule, generally accepted to-day, it is understood that living organisms, both animal and vegetable, work mainly with optically active carbon compounds, *i. e.*, compounds in which there is at least one asymmetrical carbon atom. As Kossel has expressed it, the asymmetry of the cell building stones begins the moment of the assimilation of carbon dioxide from the atmosphere by the chromophyl-containing plant cells, from whence it is carried directly to the herbivorous and indirectly to the carnivorous animals. In other words, enzymolysis as it occurs in the animal body is bound up with the chemical constitution and configuration of the substances undergoing change, so that only those substances can be transformed or decomposed that have a certain definite plan of structure. It is thus clear that the processes of nutrition are carefully ordered and clearly defined, while to follow their many paths and interpret aright the signs by the roadside requires accurate chemical and physiological knowledge.

From the early conceptions of nutrition as embodied in the work of Lavoisier and his immediate successors, we have traveled a long way. From vague generalizations based on erroneous views and faulty reasoning, we have passed to a period of scientific activity, where thoughtful observation and careful analysis have contributed to a broader and clearer understanding of the ways of nature. New points of view lie before us pregnant with meaning and full of suggestions for future work. Let us gather together all the facts available, search far and near for all the data that can be obtained bearing upon the question at issue, remembering that progress can come only from intensive and persistent investigation, and that conclusions bearing the imprint of truth must be based upon accurate knowledge. It is only when we lack knowledge that we are liable to be led astray by vain imaginings. How clearly this is illustrated by the experience of the renowned Harvey who when he was arriving at a true understanding of the circulation of the blood, by patient inquiry and still more patient dissecting, was constantly confronted by the crude and illogical views based entirely upon the speculation then prevalent! His many critics who lacked sufficient knowledge to be impressed by his careful demonstrations and who were moreover dominated by the prevalent belief in the spirits provoked from him this statement:

> With reference to the third point, or that of the spirits, it may be said tnat, as it is still a question what they are, how extant in the body, of what consistency, whether separate and distinct from the blood and solids, or mingled with these—upon each and all of these points there are so many and such conflicting opinions, that it is not wonderful that the spirits, whose nature is thus left so wholly ambiguous, should serve as the common subterfuge of

ignorance. Persons of limited information, when they are at a loss to assign a cause for anything, very commonly reply that it is done by the spirits; and so they bring the spirits into play upon all occasions; even as indifferent poets are always thrusting the gods upon the stage as a means of unraveling the plot, and bringing about the catastrophe.

Fernelius, and many others, suppose that there are aerial spirits and invisible substances. Fernelius proves that there are animal spirits, by saying that the cells in the brain are apparently unoccupied, and as nature abhors a vacuum, he concludes that in the living body they are filled with spirits, just as Erasistratus had held that, because the arteries were empty of blood, therefore they must be filled with spirits. But medical schools admit three kinds of spirits: the natural spirits flowing through the veins, the vital spirits through the arteries, and the animal spirits through the nerves; whence physicians say, out of Galen, that sometimes the parts of the brain are oppressed by sympathy, because the faculty with the essence, *i. e.*, the spirit, is overwhelmed; and sometimes this happens independently of the essence. Further, besides the three orders of influxive spirits adverted to a like number of implanted or stationary spirits seem to be acknowledged; *but we have found none of all these spirits by dissection, neither in the veins, nerves, arteries, nor other parts of living animals.*[11]

Here we have the point of view of the true investigator, the true scientific spirit. Abide by the facts and base your reasoning upon careful observation. Although Harvey lived at a period when physiological knowledge, as we understand it to-day, was almost wholly unknown, and when the influence of the "spirits" dominated all thought, yet he applied rational methods of scientific study and drew logical conclusions from his observations, with the result that to him belongs the honor of discovering the motion of the heart and the circulation of the blood. What he could not see he had no faith in, and so the theories concerning the spirits of the body he laid aside as having no foundation in fact. Would that to all of us might be given that same true appreciation of the importance of scientific observation upon which depends the advance of exact knowledge.

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[11] Quoted from William Harvey: "An Anatomical Disquisition on the Motion of the Heart and Blood in Animals," translated from the Latin by Robert Willis. Everyman's Library, London and New York.

THE UTILIZATION OF AUXILIARY ENTOMOPHAGOUS INSECTS IN THE STRUGGLE AGAINST INSECTS INJURIOUS TO AGRICULTURE

II

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Generalization of this Method. Different Applications

THE striking success brought about in the struggle against *Icerya* by the use of *Novius cardinalis* gave rise to great enthusiasm in favor of the method of fighting injurious insects by their parasites.

First in California, then in Australia and the Hawaiian Islands, under the auspices of Alex. Craw and his adepts, the application of this method became popular and enjoyed extreme favor. From the facts just given, they generalized to excess and imagined that in collecting beneficial insects and naturalizing them in the country where they proposed to use them, they would be able to check completely the plagues of agriculture.

Fight against the Fruit Fly. Compere's Mission.—No example appears to us to show better the belief inspired by this new method, the exaggerated hopes to which it gives birth, and the zeal with which it fills its promoters, than the incredible Odyssey around the world of Mr. Compere, charged at the beginning of 1903 by the government of West Australia with a mission having for its end the search for the home of the fruit fly (*Ceratitis capitata*), and of finding the parasites which in its original home should limit its propagation. This fly, which is a great plague to fruit culture in South Africa, and which has also invaded western Australia, has also for us an interest, since it is abundant in all the Mediterranean regions where it is particularly injurious to oranges in Algeria and Tunis, and which several years ago even made its appearance in the suburbs of Paris, where it attacks peaches and apricots. The *Ceratitis* has for a long time existed in Mediterranean countries, and it is from this region that it was probably transported to the Cape of Good Hope and to Australia.

It would seem, then, natural to direct one's observations first to this locality. Nevertheless, the damage accomplished by this insect in the Mediterranean region appears to be too large to warrant the conclusion that this is its original home. Spain having received the famous fly from one of its colonies, one naturally thinks of the Philip-pines; and these islands not being very far from Australia, Compere started then for that archipelago. He only passed through there, and then visited China and Japan without meeting the *Ceratitis*. From Japan he went to the United States, where the fly in question does not exist, but where in the collections and the laboratories he thought to gain facts which should throw some light upon the problem of its origin. From there he went to Spain, and there tried to learn from what region this country received the fruit fly. He was not able, however, to get any knowledge of this kind, but a large number of fruit growers told him that they remembered the time when oranges, peaches and other fruit were not damaged by the larva of this insect. Was that not sufficient to confirm his opinion that the *Ceratitis* was a fly not indigenous to Spain?

After having traversed the south of France and Italy, he went back again to Australia, and shortly afterwards departed for the Indies. In the following month of September he landed at Bombay, traveling through Hindostan, visiting the great markets as well as the orchards and the principal fruit regions around Bombay, Calcutta, Madras and Ceylon, studying the flies of the different species of fruits, as well as the parasites living at their expense, wherever he could find them. Then, always without having found the *Ceratitis* and finding nothing which could serve him in the struggle against this insect, he returned to Australia persuaded from certain indications he had collected in the United States, that the original country of the celebrated dipterous insect was Brazil. The seventh of January, 1904, he sailed, then, for South America. Arrived in Brazil, he quickly ascertained that *Ceratitis capitata* exists there in company with other flies injurious to fruit, and at the same time he observed some Ichneumonids and some beetles of the family Staphylinidæ, which were carrying on a war against the flies. If the *Ceratitis* causes, in general, only slight damage in Brazil, it can be only owing to the presence of all these natural enemies which hold it in check. And it, therefore, resulted that Brazil was the promised land for the fervent entomological traveler, the original home of the Mediterranean fruit fly! Arranging as ample a provision as possible for the parasites and predatory enemies of this insect, and arranging for their food for the time necessary for their journey, he then returned to Australia.

On his arrival, the Staphylinids were set at liberty in one of the gardens of Perth, where the conditions seemed particularly favorable to insure their subsistence. The pupæ parasitized by the Hymenoptera to the number of about 200 were placed in breeding jars, and as the parasites emerged they were liberated in the orchards most infested by the fruit fly.

If we have told with some details this story of the journey around the world of a practitioner, launched by his government into the search for the parasites of a fly, it is to show the vogue which the use of beneficial insects in the struggle against injurious insects enjoys in certain countries.

What will be the result of this experience? It is premature to express an opinion on the subject. The time necessary for the definite acclimatization of a parasite, and above all for it to multiply sufficiently to restrain the insect which it is its mission to attack, must be extremely variable, according to the species and also according to the extent of spread of the plague. It is only necessary for some months to elapse in the case of *Novius cardinalis,* but years may be necessary for such parasites as the Ichneumonids.

Utilization of Beneficial Insects in the Hawaiian Islands.—Journeys of Koebele.—The method of which we are speaking has nowhere been applied in a more extensive way than in Hawaii. These islands, ever fertile, present, as is well known, a climate extremely favorable for large number of tropical and subtropical crops. At the beginning of the American colonization, the only plants of economic importance were yams and cocoanuts, but since that time enormous numbers of useful plants, coming from all parts of the world, have been acclimatized in this rich country, and with them also have unfortunately been imported a large number of their natural enemies, among them, and the most important, scale insects and plant lice. It has been stated that the Hawaiian Islands are the paradise of these insects, since they are represented by numerous species coming from all parts of the world, which prosper there and flourish.

After having seen, in 1890, their orange and lemon trees relieved from *Icerya* by *Novius cardinalis,* the planters directed their efforts to this method in order to combat other agricultural plagues, and particularly the enemies of coffee and sugar cane.

They, therefore, gave Mr. Albert Koebele a commission to undertake this work. This entomologist, celebrated for his discovery of *Novius cardinalis,* and already employed at the same time by the State Board of Horticulture of California upon a similar mission, commenced by sending from California the Coccinellids which seemed most desirable for Hawaii, notably: *Hyperaspis undulata* Say, *Scymnus debilis* Lec, *Chilocorus bivulnerus* Muls., *Rhizobius ventralis* Er., and *R. lophantæ* Blaisd. The two latter became naturalized and constituted a useful resource for the country.

In 1893 he visited the islands and left immediately for Australia. From 1894 to 1896 he journeyed through Australia, China, Ceylon and Japan, and made during this journey numerous sendings of this insect to Hawaii and California. Among the best of these must be mentioned, in the first place, *Cryptolæmus montrouzieri* Muls., originally from Australia, where it had rendered inestimable service in destroying mealy-bugs (*Dactylopius, Eriococcus,* etc.), and which, introduced into the Hawaiian Islands, developed with a surprising rapidity, comparable to that of *Icerya* in California. This ladybird is there considered as one of the most important enemies of the scale insects of the coffee plantations, and particularly *Pulvinaria psidii,* one of the greatest enemies of this crop. *Coccinella repanda* is also naturalized and is to-day one of the most common ladybirds, and most efficacious among those which attack orange plant-lice and the plant-lice of Hibiscus and sugar cane.

In 1899, Koebele left for Australia and the Fiji Islands and made numerous sendings of ladybirds and different parasites to the Hawaiian Islands, notably to combat *Ceroplastes rubens* Mask.

At the end of 1902 the attention of planters was particularly directed to an injurious leaf-hopper on the sugar cane, *Perkinsiella saccharicida* Kirk. It was introduced from Australia in about 1897 and has since that time increased and spread and become a perfect plague for this important crop. The attempts made to introduce living parasites in California at the expense of similar leaf-hoppers having given unsatisfactory results, Koebele and Perkins left in the spring of 1904 for Australia, and during the course of that year sent to Hawaii a great number of insects parasitic or predaceous, and among them a considerable quantity of enemies of *Perkinsiella.*

Considering that the money appropriated by the government was insufficient, the Hawaiian Sugar Planters' Association did not hesitate to advance important sums in order to further the study of the question, and created itself a section of entomology in its experimental station, and has started a series of investigations exclusively upon the enemies of sugar cane and their parasites. Some remarkable monographs are now in course of publication.

The method of utilizing beneficial insects has been, during fifteen years, used with such activity that the list of useful insects which have been imported from one country to another, in order to combat the plagues of agriculture, is already very long.

We have already spoken of some of them in giving a résumé of Koebele and Compere. Omitting those which up to the present time have given only uncertain results, or which have not succeeded in naturalizing themselves, we will limit ourselves to a mention of some interesting species, either because they have fully justified the hopes founded upon their introduction, or because they appear likely to soon play an important rôle in the struggle against the enemies of agriculture.

Rhizobius in California.—Among the ladybirds must at once be mentioned *Rhizobius ventralis* Erichs. This little ladybird, of a specially dark color, very useful in Australia for the destruction of various scale insects, was introduced by Koebele into California while on his second mission to Australia in 1893. It naturalized itself and plays an important rôle in fighting the black scale of the olive. A hundred thousand of these insects were distributed in different districts. In different localities they multiplied in a prodigious way, and proved to be particularly efficacious in the moist climate of the seashore. Mr. Cooper, president of the State Board of Horticulture, had such confidence in the efficacy of this *Rhizobius* and other ladybirds that, yielding to a perhaps exaggerated enthusiasm, he renounced for a time all other intervention, and, in order to allow them to multiply at their ease, he suspended all treatment. According to him, to spray trees upon which there is *Rhizobius* is a crime and should be severely punished.[10]

Attempts to Fight the San Jose Scale by Means of Ladybirds.—The disasters caused by an insect commonly known as the San Jose scale in the United States are well known. The damage done to the fruit trees can only be compared in intensity to that done in our country by the Phylloxera, and about 1898, the fear that it would be introduced into Europe occasioned prohibitory, special legislation on the part of European states. Since it was a scale insect, it was natural to search for an enemy which would approximate the rôle of *Novius cardinalis,* but no one knew the original home of the San Jose scale.

Australia was considered for some years as responsible. Finally, they concluded that it might be Japan, and Mr. Marlatt, first assistant of the Division of Entomology, Department of Agriculture, was sent on a mission, in 1901–2, to the extreme orient to solve the question, and he established in a positive manner the fact that the original home of the San Jose scale was the north of China, where he found it occurring upon small wild apple trees, in the mountainous country. There he found, at the same time, with the scale insect a ladybird, *Chilocorus similis* Rossi, which, both in the larval and adult stages, feeds on the San Jose scale. This ladybird is an insect widely spread, not only in China, but throughout all of Asia and the south of Europe. The San Jose scale is, then, not its only food, but it can live at the expense of different scale insects. Therefore, samples of this insect, coming from China and offering the best possible conditions for adaptation to the struggle against the San Jose scale, were sent to Washington, and all precautions being taken, they were bred with great care in the Bureau of Entomology, first in cages and afterwards in an experimental orchard.

They were thus produced in sufficient quantity, so that for several years they could be sent to different States. The colonies which were

[10] The attempt to acclimatize *Rhizobius ventralis* in India and Ceylon, undertaken by Froggatt and Green, did not succeed, probably on account of unfavorable climate.

established in the north did not succeed. But, on the other hand, colonies installed in the Georgia orchards and other southern states rapidly spread, naturalized themselves, and still fill a useful rôle in attacking the San Jose scale. However this may be, this importation can never be compared to that of *Novius cardinalis*. Mr. Marlatt himself states that this insect does not seem to have found in America, up to the present time at least, conditions as favorable to its development as in its native country. Moreover, the time when it was introduced coincided with the period of employment especially of the lime-sulfur-salt wash, and obviously the use of such an efficacious remedy should not be interrupted to allow the ladybird to spread.

Scutellista cyanea.—The success gained by beneficial parasites, properly speaking, is at present rare and less startling than those which the predaceous insects, and particularly ladybirds, have brought about. An especial rank, however, should be given to a Hymenopterous parasite of the family Chalcididæ, *Scutellista cyanea* Motsch., which is among the most useful of the American importations. It was first described from Ceylon, where it was found attacking parasites of the coffee scale. Then it was found again by Berlese in Italy, where it attacked the wax scale of oranges and other plants.

Howard, with the help of Berlese, tried in 1898 to introduce it into Florida and Louisiana, to combat the wax scale, injurious in that part of the country. This first attempt at acclimatization failed. In the meantime, Lounsbury, State Entomologist at the Cape of Good Hope, drew attention to this parasite as one of the most efficacious enemies of the black scale of the olive. The olive scale is not abundant enough at the Cape to be considered as injurious, and the damage which it does is always less than in America and particularly in California. On this account, and considering *Scutellista* to be the cause, the State Board of Horticulture of California, always looking for new assistance of this kind, tried to get this parasite. In 1900–01, branches carrying parasitized black scale were sent from the Cape to California. Some parasites were obtained by breeding from these different sendings, but their number was not sufficient to undertake a rearing in the large cage constructed around the tree infested by scales, but, in 1902, numerous colonies were sent into all the districts of the State of California where the black scale was injurious. Since 1903, numerous orchards have been found which have been practically cleaned of the black scale by this parasite. It may be affirmed that this introduction is one of the most fortunate ones for fruit growers in California.[11]

The Struggle in America, by means of Parasites, against the Gipsy

[11] The acclimatization of this insect appears also to have been brought about in Australia, where it was introduced in 1904, and in Hawaii, where it was imported in 1905. Mr. Lafont has lately announced the presence of this insect in France, where he considers it a very efficacious parasite of the black scale.

Moth and Brown-tail Moth.—If parasitic insects (hymenopterous and dipterous) are at the present time behind the predatory ones, it does not make their efficacy any the less that the work that they accomplish is not so immediate and is less easily brought about.

Everybody knows how some ladybirds will free a tree from plant lice or scale insects, while there is some trouble in observing how a parasitic insect lays its eggs in the interior of a caterpillar. Moreover, while the victims of a predaceous insect are killed immediately, the insects pierced by the hymenopterous insect continue in most cases to feed and grow, and it is only in the following generation that the good work can be seen. Finally, to appreciate the just value of parasites, it should be remarked that several species, in certain cases more than thirty, live at the expense of a single plant-feeding species and join forces to hold it in check. To reestablish the equilibrium in a country into which a plant-feeding species has been imported, not only one of these parasitic species, but as many as possible, should be sought for and should be naturalized.

In a few years we will be much more certain concerning the advantages to be drawn from the utilization of these beneficial species.

No experiment in any case can be better conceived to illustrate this question than the gigantic undertaking now carried on by the government of the United States which has for its object the importation of the European parasites of Bombycids, up to the present unmasterable scourges, which ravage without interruption the trees of Massachusetts.

These two insects, *Liparis dispar* and *L. chrysorrhœa*, are European insects which have been accidentally introduced into Massachusetts, the first in 1868, and the second in 1890. It is difficult to imagine the intensity of the ravages of these two insects. The damage occasioned by the first of them, which is popularly known in America under the name of the gipsy moth, is to-day celebrated in certain localities, notably in the suburbs of Medford, which was the first point of infestation. The caterpillars became so abundant that all the trees in the parks, woods and public streets were entirely defoliated, and presented, in midsummer, a winter aspect. These trees, deprived of their vitality, were killed by thousands. In certain suburban quarters, one could see the walls of the houses carpeted with caterpillars, and the roads themselves so invaded that it was impossible to walk without crushing them by hundreds. A special committee was started to organize the fight, and from 1889 to 1895, $525,000 was spent in work against the destruction of this species. For the year 1897 alone, $150,000 was voted by the legislature.

As to *chrysorrhœa*, known to Americans under the name of the brown-tail moth, although it has shown itself extremely injurious, it is to-day eclipsed by its congener, and it is only in these later years that it has taken an importance of the first order, tending even in certain districts to take the first rank over the gipsy moth.

The caterpillars of these two species are extremely common in Europe, their original home. They are injurious and from time to time appear in great number. It is to be remarked that in a year following their large multiplication, the caterpillars of these insects become quite rare, and that they remain so for a long time. They are, then, very far from being responsible for damage similar to that which they cause every year on the other side of the Atlantic. With us their presence is tolerable, and they do not cause notice since they do not threaten the vitality of the trees. In Massachusetts, on the contrary, they constitute a permanent plague which has commenced to invade neighboring states.

The difference in these conditions appears to be that in Europe the insects are held in check by parasites, which are much more numerous than in the United States.

Some American parasites have adapted themselves to destroying the gipsy moth. There are 5 hymenopterous and 6 dipterous parasites, without counting several predaceous species which attack it. But this is small in comparison with the 27 hymenopterous and 25 dipterous parasites of the gipsy moth in Europe. While the parasites of the brown-tail moth are less known, it is perfectly sure that in Europe this insect is kept in check much more efficaciously by its natural enemies than is the case in America. On account of these considerations it was only natural to seek to introduce into Massachusetts the original parasites of these two insects. For a long time it was not judged wise to undertake the enterprise. A law obliging the systematic destruction of the gipsy moth and the use of insecticidal mixtures seemed to render it inadvisable. Moreover, there was confidence in the fact that the native parasites would increase. Now the conditions have changed. In 1900, the appropriations were stopped, at a time when the insect was well in hand. In five years, however, it has spread over a territory four times as great as that which it occupied in 1900 and has commenced to spread into the neighboring States of New Hampshire and Rhode Island.

On the other hand, in the 36 years that the insect had infested the country about Boston, American parasites, if efficacious, would have manifested it in an appreciable way. The same considerations applied to the brown-tail moth.

Americans resolved, then, to attempt a last and great effort to master the plague against which a long struggle had given insufficient results. In the appropriation bill of the Federal Congress, in 1906, $2,500 were appropriated to begin the importation of parasites of these two insects into the United States. At the same time the state of Massachusetts appropriated $10,000 a year for three years for the same end. A special superintendent, Mr. Kirkland, with a staff of agents and assistants, was charged to preside over the execution of the work in America, and Mr. Howard, during the three years 1905, 1906 and 1907, was sent on a mission to Europe to seek for the parasites of the two species, visiting France, England, Italy, Germany, Austria, Hungary and Russia. He interested in his enterprise all of the official entomological bureaus, as well as the principal specialists, who promised him their help and active cooperation.

It is by hundreds of thousands that the nests of the brown-tail moth have been sent to Boston for two winters. It is in innumerable quantities that, during the months of June and July, caterpillars and chrysalids of the two species have been sent to both destinations. All these insects, upon their arrival in Boston, where they have been received by Mr. Kirkland, are sent to a laboratory specially constructed for this work. It is in the suburbs of a small village named Saugus, in a house which is constructed in the midst of woods infested by the caterpillars of the two species. Aside from the rooms devoted to research and rearing work, this house contains the local or resident assistant, who has charge of the work, and also the specialists who are sent by the bureau from Washington, at the time when the insects are appearing. The insects are reared in boxes constructed for that purpose, and somewhat like those employed by the State Board of Horticulture of California. To avoid the issuing of hyperparasites or of suspected species not existing in America, and accidentally mixed with the sendings, the cages are kept in closed rooms with double doors. They are arranged side by side in several longitudinal rows, and so abundantly that it is difficult to walk between them. When issued, the parasites are generally not set at once at liberty, but are allowed to breed in large outside cages.

To what practical results will these experiments conduct us? It is difficult to answer this question in a decisive way. The experiments have been in any case carried on under conditions most perfectly constituted to assure the success of the enterprise, and it was impossible to confide their execution to a savant of greater authority than the eminent director of the Bureau of Entomology, at Washington. Having a great number of parasites imported, an abundance of food which they find at their disposition, and a climate which they will encounter analogous to that of Europe, it does not appear doubtful that many species will acclimatize themselves, and as soon as acclimatized, they can not fail to strongly influence the balance of nature to the prejudice of the destructive species.

The time necessary for this movement of the see-saw may be long, and it seems that one could hardly expect appreciable results before four or five years.

But what does this matter in any event? since we are trying to obtain a result of indefinite duration which will bring about exemption from the ruinous methods of destruction by insecticides and which will mark the end of a public calamity menacing the trees of the whole United States.

General Considerations and Conclusions

The exposition of facts we have presented in this memoir allows us to take stock of the importance gained during these recent years by the method of utilizing beneficial forms. It can not be denied that, practised in a judicious manner, it can render very great services, and the initiative of governments which have been encouraging large experiments destined to show its value, must be applauded. It would be bad taste indeed to criticize those who have brought about a check, for it is only by trying experiments that one can understand the conditions which may prevent success, and far from implying failure under such conditions, the experiments almost always teach a useful lesson.

Those accustomed to the experimental method and to laboratory research know well how the discovery of a new fact in science is made at the price of much groping, of misconceptions and of failures, and how these have to be conquered before the truth is learned. Is it reasonable, then, to suppose that it can be otherwise for these great experiments in economic entomology, of which we have just spoken? And if by forced circumstances those who are carrying them on can not be protected by the silence which the learned men of the laboratory enjoy, if the work which they are undertaking is exposed to distortion or exploitation by persons anxious to boast and to give out sensational information . . . these are circumstances which, to our eyes, can only add to their merit and to increase the rights which they have to our esteem.

If eulogy without reserve should be given to those who have taken part in this great movement in favor of the utilization of beneficial insects, we would have the right, on the other hand, to discuss the too-exclusive and too-optimistic conclusions to which some of the most fervent adherents of the method have been led.

It is in California above all, and in Australia, as we have said, that the theory has been formulated in the most absolute way. According to the claims of the State Board of Horticulture, of California, no insect is in its original home a pest of sufficient gravity to menace a crop in a serious way, because nature has always placed by its side a parasite capable of holding it in check. Each time that a new enemy reveals itself in a region and begins to undergo exaggerated multiplication, its orginal country should be searched for parasites living at its expense, and these should be procured and naturalized. This is, if I am not mistaken, the theory of Alex. Craw and his school.

In objection to this doctrine it should be urged that there exist insects which can be considered as veritable plagues to our crops, and which, however, are undoubtedly indigenous, such, in Europe, as the cockchafer, the apple anthonomus, the pyralis of the vine, the cochylis; and for America, the Colorado potato beetle, which would have ruined the culture of the potato in the United States if the use of Paris green had not been discovered.

But other stronger objections may be urged, if not against the principle of the theory, at least against its too great application and against the exclusive way in which it has been propounded. Admitting that it is incontestible that certain insects can become terrible plagues where they are introduced into a new country because they are not accompanied there by their natural enemies, it is manifestly going too far to hold that it is always to the absence of the natural enemies of an insect of exotic origin, taking the proportions of a plague, that it owes its virulence.

We know well, for example, that it is for entirely different causes, depending upon the nature of the affected plants, that the Phylloxera occasioned an unprecedented disaster in Europe; and it would have been taking a false step at the time of invasion of this insect to undertake long researches to procure its natural enemies.

An indigenous insect, which has been for a long time practically harmless, can become more dangerous and even arrive at the condition of a plague simply because man, by new crop conditions, in favoring the extension of some plants at the expense of others, and substituting for an extremely varied natural vegetation an immense supply of a single plant, has himself broken the equilibrium of nature and favored to a very large degree the multiplication of the insects that attack his privileged crop. It is in the same order of things that an insect living upon a wild plant becomes adapted to a cultivated plant, and multiplies excessively at the expense of the cultivated plant whose conditions are particularly favorable to its nutrition. One of the most striking examples of this phenomenon is the case of the Colorado potato beetle, of which we have already spoken. This insect, originally from the Rocky Mountains, lived solely upon wild Solanum, but about 1855 it invaded the potato fields which began to be cultivated in its country, and then gradually spread into all of the potato fields of the United States and Canada, causing terrible damage.

Finally, it is not necessary to believe any longer that all exotic enemies, whose appearance is signalized by extreme virulence, will bring disaster unless their natural enemies are introduced. It is rational to believe, on the contrary, that at the end of a longer or shorter period there will be brought about an accommodation between the plants and their enemies, analogous to that which is produced between animals and bacterial, trypanosome or piroplasmic diseases. It is well demonstrated that certain insects like the scale insects inoculate in the sap certain toxic products, and it happens that varieties of plants that have never been attacked before by these insects are at first peculiarly subject to their action, then at the end of a longer or shorter time they begin to acquire a relative immunity—an immunity acquired in a way quite different from the formation of anti-toxins may be conceived, that is to say, an immunity attributable to many defensive adaptations of the plant, consisting in modifications of the plant tissue and tending either to render the attack of the insect more difficult, or to diminish the quantity of food which it can get, or again to render the lesions which it produces less dangerous.

If, for example, the San Jose scale is less injurious in its native country, can it be said that this is the case only because of the parasites which hold it in check? Are there not serious reasons for admitting that the trees of this country may be formed of varieties adapted to this insect, capable of resisting it?

Finally, we should also take into consideration the fact that if, during the first years following its introduction, an injurious species of exotic origin can multiply freely without any parasite to interrupt its multiplication, there often comes a time sooner or later when the parasites of a country living at the expense of the indigenous forms most nearly related to the exotic species progressively adapt themselves to the latter and end in limiting its propagation. This cause, added to the progressive adaptation of plants, appears to be bringing about the actual diminution of the virulence of the San Jose scale in America.

It results from what precedes that in the problem with which we are occupying ourselves the factors are multiple, and that it will be a great mistake to consider one or the other and not all.

If, because of the too absolute manner in which it has been formulated, the theory of the utilization of beneficial insects must surrender somewhat, it is necessary also to point out the errors and the exaggeraions to which it has given rise in practise, for they give rise to excessive hopes, provoke serious disillusions, and are a discredit to the whole method.

In the first place, a grave fault resulting from an excessive confidence in the action of parasites consists in advising the suppression of insecticides in a region where it is desired to acclimatize the beneficial species. In the great majority of cases, at least in regions where insecticides are employed with success to hold a crop enemy in check, the desire to acclimatize a beneficial species should not cause the general use of sprays to be stopped. The two methods are not incompatible, for in a given region it is very rare that you can regularly spray all of the trees. This one, or others, will not be treated, and the ladybirds and other useful insects will therefore have a free field to carry on their beneficial work, and centers from which they can be dispersed will be created.

One of the greatest dangers in introductions consists of the possibility of introducing into a region an animal which considered as useful in its original home, is capable of becoming absolutely injurious in the new country into which it is introduced, on account of the conditions of the environment which it encounters. The examples of the sparrow imported from Europe into America and Australia, of the mongoose introduced from the East Indies into the West Indies, of the rabbit imported from Europe into Australia, are too well known to be described. It has been stated that no danger of this sort exists in such cases as these, since parasitic insects of other insects can live only at the expense of these last, and it is the same with predaceous insects. There is no doubt of this, but there exists another danger of a direct character in the importation of the insects which are desired for acclimatization, and that is the danger of importing at the same time either injurious insects sent along as food, or hyperparasites which can prevent the propagation of the useful insects and which becoming acclimatized themselves, endanger even certain useful indigenous species.

It is very easy to take the necessary precautions so that the insects which serve as food during the journey should present no danger, and it will suffice to make sure that they belong to a species existing already in the region where they are to be acclimatized.

The history of the naturalization of *Icerya purchasi* in Florida shows us that the method of utilization of beneficial insects, practised by incompetent people, may have sad consequences.

As to the danger from hyperparasites, while it is apparently not so serious as the preceding, it is, on the other hand, much more difficult to avoid. Preliminary rearings are necessary before the beneficial species are definitely set at liberty, and all precautions are necessary after the issuing to separate the primary parasites from the hyperparasites. It is for this reason that the application of the method of the utilization of beneficial insects, in order to render all the services which are expected of it, should be carried on indispensably and exclusively by learned men, especially informed concerning insects and their reciprocal and biological relations.

We have shown in this memoir about all that can be drawn from the utilization of predatory and parasitic insects in the struggle against enemies of crops. One conclusion may be drawn also from this study, and that is that one can not count upon beneficial forms as a substitute for the methods of destruction commonly used in applied entomology. Their rôle does not consist of exterminating a species, but of maintaining a natural equilibrium, or of reestablishing it when it has been disturbed by human intervention. In such cases, their action can make itself felt in a more or less prompt way. It may happen that, immediately after having been imported into a country, they stop with an extraordinary rapidity the plague which they have been brought to combat. This was the case with *Novius cardinalis,* in California, and in different countries. It was also the case for *Crypotolæmus montrouzieri,* which made very rapid spread in Hawaii. It must be stated, nevertheless, that this is rather exceptional and that, in general, a number of years are required—the number varying according to the species and to the circumstances under which it is brought—before it can be completely naturalized in a given country, and before, thanks to its spread, it brings about a sufficient retardation of the multiplication of the plant-feeding species for which it is imported, to reduce it from the condition of a scourge to that of a supportable species.

The services that parasites and predaceous species render are sufficiently great so that there is no necessity for exaggerating them.

Far from lulling ourselves with illusions, we should keep on the watch and foresee the dangers with which other injurious species menace us, such as *Icerya purchasi,* which may any day invade Provence or Algeria on plants imported from Portugal and Italy.

There is no doubt that, however great may be the efficaciousness of a ladybird, like *Novius cardinalis,* it will be still better not to have the enemy at all than to be obliged to fight it by the intervention of its natural foe. We do not know that *Novius cardinalis* will with us develop with the success which marked its spread in California, in Portugal, and in Italy. We are ignorant whether the climatic influences or some parasite, recently adapted to this new strange host, will not limit its propagation and diminish its beneficial action. Finally, other plagues than *Icerya* menace us, and it is unfortunately certain that not all of these may be mastered by the equivalent of *Novius cardinalis.*

Confidence in the assistance which we can get occasionally from parasites and predaceous insects should not make us lose all prudence nor prevent us from seeking a guard against the perils which surround us, in organizing at our large ports an inspection and disinfection service like those which have been started at foreign ports, notably Hamburg, and in a general way taking every measure possible to protect our crops.

OF THE SOIL OF THE EARTH

By SPENCER TROTTER
SWARTHMORE COLLEGE

ONCE upon a time—certainly more than two hundred years ago and no man knows how long a time before—an aboriginal folk fished in the waters of the West Fork of Brandywine. The remains of an old breastwork of stones point to the former site of a dam, connected probably with a rude sort of weir. Such is the tradition handed down through several generations in the family of an alien occupant of the land. This occupant and his descendants to the present time have never permitted the ancient work to be disturbed, a rare and kindly virtue in these days of scant sentiment. Only the unhindered stream has worked its will. Not far from this dam, on a low rise of land overlooking the valley, stands a scattered group of trees—white oak and shellbark hickory—and here, again tradition has it, this aboriginal folk buried its dead. Certain it is that the alien occupant, though he ploughed deeply all about, likewise left this spot sacred to the hand of time. The site is not marked by any tumuli; only the level ground appears a trifle more grassy in some places, more springy under the foot, which lends color to the tradition of long-forgotten graves.

It was beyond a question that somewhere in this ground the mortal traces of a man lay scattered—hidden as completely as in that prior time of his being when as yet there was none of them. Deep in some maternal tissue there had once been that marvelous gathering together of elements—that ever-repeated miracle of the fashioning of a form of life. Where no light was there was yet the molding of a structure that in the days to come would be responsive to the light and to every play of color; a structure that would hold wonderful pictures of land and sea and sky. Where no sound was there was yet the molding of another structure that would come to know the sympathetic voice, the springtime song of birds, the multitudinous sounds of the forest, the droning cadence of streams. In the depths of this nebulous man another structure was being spun out of the life stuff, one that would come to hold all that the sights and the sounds had to tell, that would interpret their meanings, that would come to feel and to know, to remember and to wonder. And yet in this dark fountain-head of being there was no hint of such future possibilities. All through this formative man the delicate threads of life were spun between the central brain and its outposts that in the end he might know himself and all that went about him. Bit by bit bone and muscle, ligament and sinew, were pieced together—strange artifices to do the brain's bidding. The heart began as a throbbing pool of blood, the red current of which found its devious way to every nook and cranny of the rapidly growing form. Long before the possibility of air ever reaching into these depths of dawning life the lungs were fashioned, and the mouth and stomach were prophecies of the hunger to come.

Each particle of life matter that went into the building of this man was indelibly stamped with the impress of inheritance. He was fashioned after his kind. When he finally appeared among his people and as he grew into manhood the bronze color of his skin, the straight black hair, the dark iris, the long head with its high arched cheeks, betokened the stock from which he sprang. His ways and his speech were those of his ancestors. The more remote of these ancestors had come from a hyperborean land at a time far back in the dim, unrecorded lapse of millennia beyond the reach of tradition—a forgotten dream period like that before birth. These ancient men without doubt saw the mastodon in the flesh, as our cave-dwelling ancestors over the seas beheld the mammoth. Successive generations of them may have witnessed the floods of the melting ice-sheet and the changing features of lake and river basins. A later horde, within the period of tradition, crossed the River of Fish (Namæsi Sipu), fought and drove out an ancient people—the Alligewi—who dwelt in the forest land to the east of the great river and whose curious earthworks remain to this day, and finally reached the place at the rising of the sun, beyond the mountains (Alleghany), by the shores of the Great Lake of Saltwater. Such is the meager thread of this man's race history.

Through the lapse of time with its shifting scenes the never-ending drama of the generations of men goes on—birth, and the span of life, and death. One indestructible thread is woven into this tissue of humanity—the thread of inheritance that reaches back, like the strands of a cable, into abysmal depths. This subtle thread of inheritance that runs through the generations had made this man what he was and had cast him into his time and place. And the end of it all is an unknown grave, as it is with Homer and Cæsar, and the innumerable host of men, small and great, that have ever lived.

In the waning light of a November afternoon I found the man where he had lain these two hundred years or more imbedded deep in the soil of the earth. The sockets in which the light of life once gleamed, the cavernous nares through which the smells of young April poured into the brain; the bony ear canals that once rang to the rhythm of the stream; the mouth place resonant with its strange speech—all plugged solid with the clay. The very bones themselves had taken on the earthy hue and texture, crumbling into fine dust. A few enduring bits of handiwork—quartz pebbles which had been laboriously bored through for a bead string, a brass finger-ring, a curious piece of shell—were scattered about in the clay; simple things that seemed to mock the less enduring framework of life.

The one haunting thought, after the emotional and scientific elements of the mind had satisfied themselves, was that this man, this aborigine, whosoever he may have been in the flesh, had resolved into nature. There was no victory about this sepulture. The earth had simply taken this man again to herself, and as she had molded him from her clay and built him up out of her breast milk and her maize and beans and the flesh of her fish and fowl, so now she was gently and leisurely scattering the molecules that her magic hand had once so artfully put together. Here then, methinks, is the plain tale of all men.

The sun sank behind the Brandywine hills; the light of the western sky faded and with it the outline and color of the landscape. The first few stars twinkled dimly overhead. The filling crescent of the moon hung low in the darkling west and passed out of sight. The Dipper turned slowly across the northern arc. The dawn light of a new day came into the east. It was the never-ending change of the eternal background. Countless generations of men had passed, their very existence forgotten—blotted out in the lapse of time—and still the everlasting shift from day to night, from night to day, went ceaselessly on. Of what account was this man or all the millions of men that had lived only to be forgotten—lost in the soil of the earth?

As the thread of inheritance is seemingly indestructible so far as the race of men is concerned, there appears still another manifestation of immortality, of a purely individual character, which appeals to every man as an element of his being that must outlast the things of time. Just what this is has never been vouchsafed to any man to know. It is the eternal riddle of life, the hopeless tangle of all mythology and philosophy throughout the ages. Mankind has ever found itself in a world of material facts and elemental forces the manifestations of which have revealed a vast environment of the unknown. What a man calls his soul is the recognition of this unknown which lies beyond the reach of his senses. The mind has explored a half-way region—a region of principles and forces—and has analyzed these with some degree of surety. Beyond this, on the boundless ocean of infinity, the chart and compass of the mind are of no avail. Men have framed theories of this outer realm far more crude and improbable than any notion entertained of the outer geography of the Odyssey and they have peopled it with beings quite as improbable as those encountered by the adventurous Ithacan. More than this, mankind in every age and in every state of society holds to the belief, more or less crude in its conception, that at the dissolution of the body the individual ego, soul, elusive psyche, will burst through the barrier of the material and pass into the limitless realm of the unknown.

Through the medium of his sense organs a man perceives the material portion of his environment, at least that part of it that can affect these nervous structures. The mind, however, reaches out beyond the frontiers of sense and has divined the existence of those supreme elemental forces that mold and shape the material universe. But not a hint comes from these efforts of mind and sense as to the great underlying question of the unknown. On this question, I take it, the primitive pagan is as enlightened as the most accomplished philosopher.

Touching the fact that a man's recognition of the unknown comes through the amplitude of his being, it becomes a matter of no small moment that this being is a state of living within the domain of a material environment. Whatever is discerned of the unknown environment can not come else than through natural means, for man is not greater than nature. Moreover the unknown is not a supernatural realm, nor is what man calls the soul a supernatural portion of his being. Both alike are indeterminable elements within the sphere of natural law and are supernatural only so far as they are indeterminable and represent an unknown quantity in our comprehension of the universe. Seeing that knowledge can not accomplish this end of knowing the unknowable, it remains for a man to know himself as a part of nature, which, so far as may be discerned, is working toward some vast purpose. It is surely no part of the scheme for him to blind himself with false ideas and vain imaginings about a hereafter. His work is to live the life of the great animal type into which he has developed, uplifted by all that comes to him through his exalted brain structure.

Research into the nature of things, which characterizes the modern scientific attitude of mind, is unquestionably a means toward a fuller appreciation of the conditions of existence. This does not necessarily imply, however, that the pagan's philosophy of life is altogether a failure. There is a warmth and vitality in the pagan view of nature which the scientific mind has never attained. The poet comes nearer to this, since the poet and the pagan alike personify the forces of nature and idealize the facts of life and environment. And it is on this idealization of the facts that men build their joy in life. This man of the Brandywine knew nothing of molecules or of the ultra-violet ray, yet he surely knew the joy of the opening spring. He was not versed in the geological history of his locality, but the hills and the stream were part of his very life and he read their story in his own way. The voices of the forest spoke to him in a language unknown to men of a less wild strain of blood. There was a personality like unto himself in each beast, bird and fish that he knew; a *genius loci* in every waterfall and mountain glen. The forces of nature were personal elements in his philosophy. He lived, this man of the long-forgotten past, as all men live—getting his food, begetting his kind, loving, hating, fighting, rejoicing in the coming of the spring, pleased with his own person and its adornment, repeating the tales of his forefathers about the fire—then vanishing into the all-containing soil of the earth whence he came.

What man, once quickened by the spirit of the earth and touched by its thousand sweet influences, would ever think of resigning this mortal inheritance, with all its certainty of dissolution, for an immortality in some unknown, untried sphere of existence? The perennially hopeful day; the charm of sex; the friendliness of fellowship; the mating of man and woman; the birth and nurture of children; the buffet of the elements; the warmth and glow of fire; the delight of working muscles; memory-haunting smells; food and drink; labor and rest; the night and sleep—these are man's heritage and joy.

If the old pagan spirit still dwells in the hearts of men it surely makes for the best and sweetest that life holds. In this spirit a man may come to regard the dissolution of his body with some degree of complacency, knowing that his mortal parts will again become incorporate with the soil of the earth, and the grass, and the all-sustaining air—things which entered into his being through all the days of his life—and yet trusting that the best of him—the part that found joy in living—will still find joy, somehow and somewhere, in the realm of beneficent nature.

THE CONSERVATION OF THE GREAT MARINE VERTEBRATES: IMMINENT DESTRUCTION OF THE WEALTH OF THE SEAS

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THE rapidity with which our large wild animals are being destroyed at the present time is scarcely realized, to say nothing of the threatened introduction of a noiseless gun. Because this or that species is usually considered by itself, it is not generally noted that in the aggregate there is scarcely a single feral form large enough to attract the bullet of the hunter but is foredoomed to speedy extermination if a public sentiment mighty to save is not soon aroused; and such sentiment must cross and recross political boundaries, must be world-wide, to be wholly effective.

Much has been said about the preservation of various birds and land mammals; but with the exception of the seal, the passing of the great animals of the sea provokes little comment. Indeed, their protection or conservation is commonly deemed impossible or not worth the while, it being invariably overlooked that not a single great animal of the sea, unless of extreme rarity like some of the gigantic cuttle-fishes, is without a large economic value, and thus always sooner or later the object of an exterminating hunt. Much less is the zoologic value considered—that intrinsic side which passes far beyond more obvious utility into the domain of the philosophic, and lends to sea and land a mighty charm.

Contrariwise, students of animal history and distribution, and more especially those who go back and study the fossil record as well, can not fail to observe with alarm the unremitting warfare against all the animal kind, that, extending far into the prehistoric period to the great land turtles and moas, has with the exploration of the remote places of the earth and the arming of every savage tribe with modern weapons, become a heedless *debacle*. It is therefore simply in the performance of a plain every-day duty that in recent annual mid-winter meetings of various scientific societies there has been brought forward for discussion, on a broad basis, the question of animal conservation on a large scale. We may especially cite the resolution passed unanimously by the American Society of Vertebrate Paleontologists at New Haven, as follows:

Resolved, That the American Society of Vertebrate Paleontologists will aid in any way practicable those measures legislative, international and local which will prevent the now imminent extermination of the great marine vertebrates, especially the cetaceans and manatees, seals, green and other turtles on the coasts of the United States, or on the high seas.

This resolution was also adopted as its own by the American Association for the Advancement of Science at its Chicago meeting, and very similar action has been taken by the New York Zoological Society looking to needed action by congress. Many evidences of a world-wide interest are at hand.

The Thousand-year Hunt of the Whales

The first of the great cetaceans to be hunted, was the Biscayan whale, *Balœna glacialis.* Its capture was begun in the ninth century by the Bisques and soon taken up by others. Following extermination in the Gascoigne Bay, the hunt was slowly pushed northward to Finland and Iceland, and along the western Atlantic; it being even possible that whalers visited the Newfoundland shores long previous to the discoveries of Columbus. The relentless warfare to which the Biscayan whale was subjected for hundreds of years culminated in the sixteenth century and only stopped short of total extinction through the extension of the fisheries to the far north and discovery of the greater value of the Greenland whale, *Balœna mysticetus.*

The capture of the latter began in 1612 in the open waters between Spitzbergen and Greenland, and soon extended to Davis Strait and Baffin Bay. After two hundred years of unceasing pursuit this whale was driven to the remote places of the Arctic Ocean, and is now so nearly extinct that its recovery in numbers is doubtful. It may be too late to save this form; although from 1669 to 1778 it yielded to 14,167 Dutch vessels 57,590 catches worth $16,000,000 net. But this is only one of the many killings of the proverbial goose that laid the golden eggs, and a cruel enough one too. Scoresby says, in speaking of this timid whale of strictly arctic range, that it shows an affection for its young which "would do honor to the superior intelligence of human beings"; but being a trader as well as observer he adds that "the value of the prize . . . can not be sacrificed to the feelings of compassion!"

After the virtual extermination of these two more valuable species the merciless hunt was diverted to the much wilder finback whale, *Balœnoptera physalis,* now in turn with still other forms destined to extinction if restrictive measures are not soon taken. For in these days of steam, and electric light that robs the long arctic night of its terrors, the whale chase goes on very fast. The shot harpoon,[1] the

[1] Invented by Sven Foyn about 1870, by which time, owing to wildness and scarcity of the whales, the older methods of capture were no longer capable of returning a profit. Foyn was at first a sealer.

most extraordinary weapon ever used by man in his pursuit of helpless animals, is doing its deadly work at a rate that does not permit delay.

No effective measure has yet been taken; although man has actually made his first pause in the brutal butchery and reckless waste of the whale kind, begun a thousand years ago, and now nearing an end hastened in geometric proportion by modern invention.

The capture of the finback and other whales is indeed forbidden in the Norwegian fjords, but this is of little avail; for, unfortunately, the whales visiting the Scandinavian coast to calve and feed their young make a round into the far northern waters about the Bear Island and Spitzbergen, and are there slaughtered just as inevitably. When I was at the Bear Island whaling establishment early in July last I was informed that up to that time the season's catch already numbered forty-seven; and the evidence on every hand, the several thousand barrels of oil on the hillside, the skeleton-lined shore, the thousands of carrion-eating birds, and the trying-out works that sent up an odor that literally smelled to heaven as it floated away for miles over mountain, valley and snow field—all these told the story of short-sighted human greed better than records.

This reckless arctic hunt is now largely confined to the finback, to *Balænoptera borealis,* to the gigantic blue whale, *Balænopteris musculus,* and to *Megaptera longimana.* It is a bloody hunt, occurring when the females, which show throughout an extraordinary affection, are suckling their young.

The most recently attacked form is the bottle-nose, *Hyperoodon rostratus;* and just twenty-seven years have brought this superb gregarious animal to the verge of extinction; for although worth but a few hundred dollars each, this species is easy to catch. Unlike the fierce and wary "*cachalot,*" its wondering curiosity and lack of fear makes it easy prey.

For the greater part, however, the whale butchery is, for a second time, being transferred to the Antarctic, where, after an interim of fifty years, whales are again more plentiful, showing very conclusively the need of exact study of the habits of the whale and an international police patrol. So far as we are monetarily concerned, it may be stated that the whaling industry of the United States, north and south, from 1835 to the wane of the fisheries about 1872, yielded oil and bone worth $272,000,000; this vast sum being the net from 19,943 voyages with a capture of 300,000 whales.

The total capture of all the species of whale mentioned above may well fall short of 1,000,000 individuals—certainly a limited number when we consider a hunt that has occupied the maritime nations of the globe for quite 1,000 years, and a number, moreover, that warns us how very liable to extinction are all enormous and highly specialized mammals. Evidently the values destroyed in the unreasoning hunt must already be several times as great as the market price of the product secured, to say nothing of the future. It is apparent enough that even if we deny to animals the right to live that Professor Nathorst has so justly and so eloquently maintained they have, the reduction of our problem to the sordid standard demands immediate action. Certainly no one need be reminded that it has taken nature millions of years to evolve the whales, and that it is unlikely that the feat can be again duplicated on this planet.

The great destruction of the whales is, as we see, then, mainly modern; the first six or seven hundred years of hunting previous to the use of swift launches were not so noticeably destructive. Perhaps the manner in which large animal species living under strenuous conditions and necessarily breeding slowly are so swiftly destroyed in modern times can be understood better in the case of a land form like the musk ox, to which I may briefly advert. Half sheep, half ox, this curiously interesting animal, yielding in quantity a strong under wool with a texture as fine as silk, is confined solely to the treeless arctic wastes of North America and the islands to the north; its habitat originally extended from Hudson Bay westerly to the Mackenzie River, and all through Baffin Land, and Ellesmere Land to northernmost Greenland. Though the musk ox, despite this wide range, is now becoming exceedingly scarce. Cut off by the white hunter everywhere to the south, the Eskimo of the far north, always hard on the musk ox, have at last obtained guns and are now killing the northern remnants of the original herd. Thus is this hapless denizen of the most inhospitable regions of the earth being ground between the upper and nether millstone.

As such a process must have a speedy end, it is greatly to be hoped that the musk ox can be introduced into Alaska, and that the Canadian and United States governments may soon take this subject up conjointly. It is most unfortunate that the recent Swedish attempt to introduce musk oxen into Jämtland, southern Lapland, has failed owing to local parasitic enemies.

Destruction of Our Sea Turtles

Taking up another group of great sea animals; no chapter in the story of destruction is quite so harrowing as that of the sea turtles of the southern coasts and islands of the United States—the more so because it is not only the original supply that has been cut off, but because there is not the least doubt but that the turtles can with slight expense be increased vastly beyond any numbers ever observed in purely natural environments.

The problem of conserving and increasing the plant-eating green turtle and the animal-eating hawksbill, which yields the tortoise shell of commerce, should be definitely taken up, and solved. The original numbers of these forms in the natural state were always limited by the helplessness of the young when first hatched. With a shell at first very soft, great numbers are eaten by the shore birds of prey before even reaching the comparative safety of the water after floundering out of the sand where the eggs were laid. And once in the water the young are still for a time the prey of sharks, so that of the hundred or more that emerge from a single hatching a very few survive these early dangers to reach adult size. This helplessness may, however, be readily tided over by only the slightest protection, as the young grow very rapidly, and the shell soon thickens. If all shores where the green and hawksbill turtles lay their eggs were guarded by law enforced, and the young safely piloted to the water and perhaps fed for a few times only, it is evident, remembering the unvarying habit of the females to return to the same shores to lay their eggs, that the great pasturing and foraging grounds of our southern waters could be made to teem with these turtles. Audubon gives a vivid account of the Florida "turtlers" and the abundance of the turtles in his day; though these original numbers can doubtless be increased twentyfold.

Yet it has come to pass that the United States Bureau of Fisheries has not during several years of effort been able to secure any eggs of the green turtle whatever on our shores. Nor will it be otherwise with the less palatable loggerhead in a very few years, if as at present, even the employees of the Coast Service, part of whose duties it should certainly be to protect these animals, continue as now to be the chief agents of their destruction. Even on the Dry Tortugas within shadow of the Marine Laboratory of the Carnegie Institution the lighthouse keeper whiles away the night searching up and down the long white sandy beach for turtles; and save in a fog, every time a female turtle flounders helplessly on to the beach to lay her eggs our friend of the lighthouse signals with a warning horn to the "beach combers" and "conchs" who rush up and despatch the egg-bearing female. These "conchs," are indeed an evolving type of very hungry beachers who, now that game is scarce, "*close*" on everything from a wrecked schooner to a stranded turtle or whale.

Protection of All the Great Marine Vertebrates is Feasible

Certainly the "beacher," the "conch" and the "sea wolf" are as interesting as the animals they destroy, and within certain very specific limits may deserve perpetuation! Meantime, for the sake of the preservation of both, as well as the superior rights of those dwelling inland—the greater number interested in the question of the eminent domain of the sea—it is needed to quickly demonstrate the fact that the world will not tolerate needless slaughter of its anciently evolved animals, least of all when this incurs values *incalculably* greater *than those represented by the seals* alone.

All phases of this question which can be handled locally, and such are the more urgent phases, should be so handled by the proper bureaus, already in existence, backed by unmistakably knowing public sentiment. Sequentially the system of international safeguarding should be extended and perfected—the same system that has been already invoked for the seals, by reason of the fact that they yield that woman's garment—the seal-skin cloak. Only when all the sea animals are considered will this system ever be effective in the case of any single species; and somewhat setting aside altruism, it does seem strange that the immense values of the whales and turtles should have been so persistently overlooked. On the other hand, a very great altruistic value is also involved. For all international movements leading to the reasonable use of naval equipment in patrolling all the seas for the sake of common and world-wide interests and sympathies—those causes at once humane and wealth-conserving, must thrice bless.

It is, then, we must emphatically insist, neither Utopian nor impractical to attempt and speedily carry out the measures required for the preservation not only of land animals, but of all our great animals of the sea. The only element of doubt is whether the volume of sentiment can soon enough make itself felt—in short, whether the race has reached the required culture stage in time. Science has laid low the fallacious theory of fabulous gold dissolved in the waters of the seas, and we no longer heed this phantom of wealth which has deluded credulous minds quite since the days of alchemy. Nevertheless, this old belief may yet find a certain large measure of prophetic fulfillment if man can overcome his habits of wanton destruction before our great marine animals are extinct and the possibility of their preservation on this planet gone forever.

To be practical, every zoological text-book should have its chapter on the conservation of the animals of the land and sea. None should be forgotten, as many must inevitably be if the subject of conservation is not taken up in its broadest phases and based on first principles in order that specific applications may be both general and intelligent. And such teaching and applications, at once interesting, useful and elevating, should make their way into every district school. It may well be doubted if the human kind will ever be merciful to itself without being first merciful to the beast kind. For use and domestication do not constitute cruelty, since in natural environments the end of the individual is always violent—that is the weak are captured by the hunting animals, and the lion starves when no longer able to hunt. Conversely, to exterminate the forms of the sea and land is repulsive. What a degrading, miserable story is that of the hunt of the sea otter.

THE WHITER PITTSBURGH

By JOHN F. CARGILL
PITTSBURGH, PA.

IT has very happily been said that the location of the city of Pittsburgh was decided in the Carboniferous age of our planet. Equally true it is that, uncounted ages before the primal granite was clothed in verdure which "the creeping centuries" drew from surrounding air, some happening in far-away nebular space—some law of gravitation or propulsion determined the soft coal deposits, and the three branching rivers of later age. These things influenced and prearranged the site of the Iron City. If the widest range were given to imagination, perhaps it might be argued, too, that the all-enfolding laws shaped even the course of modern industry—declaring what manner of people should become the city's builders. But it is not the purpose of this article to raise any question of law *versus* foreordination.

The early settlers in the Pittsburgh district were largely composed of Scotch-Irish; a stock rugged and honest, that has, individually and collectively, assisted in the making of more world history within the past three hundred years than any nationality has ever done within a similar period. The unleavened Scotch-Irishman can hardly be described as of fascinating or lovable personality; but empires have never been founded or perpetuated by qualities sweetly lovable. Strength and determination are the essentials; and "rugged and honest" is a fair designation. Many another people might well covet one so good.

He has usually been punctilious in his dealings, reliable and moral: a considerate husband and father, religious, Calvinistic, opinionated, self-sufficient, blunt and austere. He is little interested in literature, or in science except in so far as it might contribute to his immediate business interests. The Bible is, in the main, he thinks, sufficient for literature and the conduct of life. (The reference is not so much to the comparatively modified and composite man of to-day as to the generation that is passing.) In character and temperament he is radically different from the New Englanders who settled some of our other bustling cities to the north and west; but no man is in position to say that, so far as material results are concerned, the Pittsburgher has not availed himself to the utmost of his opportunities.

Before the war of the rebellion, Pittsburgh was of comparatively little consequence. There was a town here, which had called itself a city for more than fifty years. Situated at the junction of three rivers, the waterways furnished the means of traffic. But there was little business; no capital invested from the outside; none of the present-day commercial enterprise. Every small manufacturer was a workman, and furnished his own capital. Such statistics as we have of the decade before the war show that all combined the little furnaces and factories used somewhat more than three hundred thousand tons of coal per annum. In 1906 forty-six million tons were mined in the Pittsburgh district. Farming and matters relating to river traffic were the greater industries, and Pittsburgh was the market and outfitting emporium west of the Alleghenies.

When at length a little charcoal iron began to be produced, the sturdy artisans of Pittsburgh worked some of it up into articles such as plows, axes, saws, scythes and other farm implements; locks, scales and malleable iron castings. But the Pittsburgher did not reach out after business; he scarcely even asked for it; all of which is in conformity with the Scotch-Irish principle of stubbornness. He did not advertise, nor send out salesmen. It has been said that not a traveling salesman was sent out of Pittsburgh before the war. Whereas the Yankee business man of other western towns went after trade, the Pittsburgher's attitude was that of confident indifferentism. "This is the head of navigation," he would say—"everything has got to come here, sooner or later." And he was right. Whether he builded better than he knew, we can not say; but events have proved that his industrial fortress was impregnable.

It was during the years of the war, and the period immediately subsequent, that Pittsburgh "found herself." The first oil discovery was made just prior to the actual breach between the north and south; and the production of oil, added to the other resources of the region, gave a new impulse to the industrial situation. The terrible years from 1860 to 1865 stimulated rather than depressed business conditions in Pittsburgh; since the needs of the War Department, of outfitting, furnishing of arms and armament, building of river craft and gunboats, and the point of vantage that was offered for the transfer and transportation of troops and supplies, were tremendous factors.

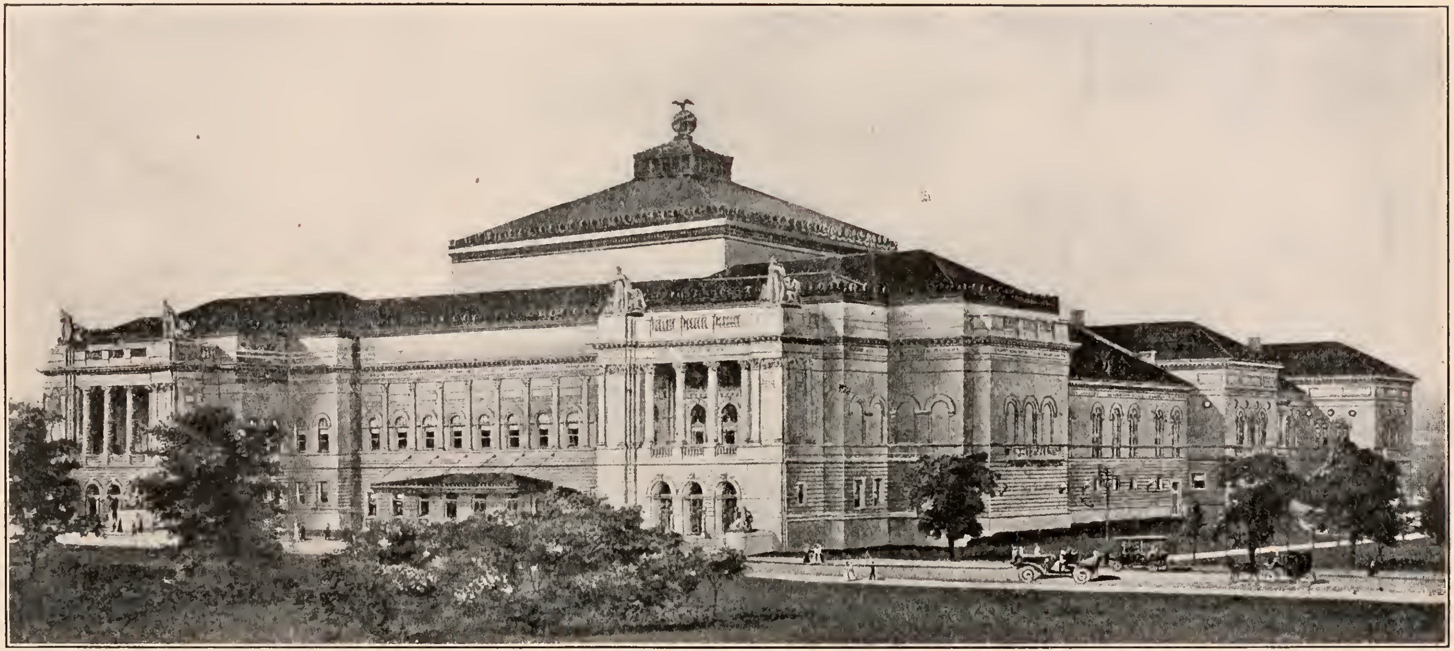
The things that have made for the development of Pittsburgh in the last generation have been set forth and printed and distributed the country over, and translated into all the languages of the globe. To try to enumerate them would involve a burdensome task, unnecessary to the present article; and only a few leading figures may be given, merely to suggest what is now being done.

The coal production of 1906 has been stated at 46,000,000 tons; the figures for 1907 being not yet accessible. The traffic tonnage, by rail and river for the same period was 122,000,000 tons; 12,000,000 tons having descended the Ohio River from Pittsburgh. The traction cars carried during the year 200,000,000 people. The total bank deposits at the close of the year were over $340,000,000. The real estate sales were over $70,000,000. The present population of Greater Pittsburgh (Pittsburgh and Allegheny) is conservatively placed at over 550,000.

The figures of the total output of furnaces, mills and factories are so enormous as almost to set present estimates at defiance. Such a wonderful era of prosperity, such wonderful opportunities for swift acquisition of riches have never been witnessed in the world before; and certain resulting effects have been witnessed which might have been foreseen. That these effects are not at all surprising—that they are not widely prevalent, and might reasonably have been expected to be much greater, can be easily shown. The habit appears to have become chronic among professional paragraphers to assume a necessary decay of manhood as a resultant of accumulated wealth. But Goldsmith would have been the first to declare himself merely a licensed poet; that he molded no prophetic verse.

In view of the city's far-reaching reputation for grime and unloveliness, it would seem well to mention a fact that is cause for general surprise to visitors, namely, the beautifying of streets and parks, and the construction of fine driveways in the suburbs. The natural beauty of western Pennsylvania can only be realized when one leaves the business part of the city and plunges into the districts adjacent, where conditions are found that suggest what must have existed before man's transforming had converted the earth to his own uses. It is doubtful whether any community, east or west, has done so much in so short a time, to make the surrounding country accessible. In various directions about Pittsburgh fine, hard, smooth macadam roads extend for many miles. Even roundabout some of the suburban towns, as Sewickley, twelve miles down the Ohio, one can travel by carriage or automobile over excellent roads for long distances through a region showing diversified scenery of great beauty.

Fine parks were never more essential anywhere than in Pittsburgh; and it is mainly owing to the munificent generosity of Mrs. Mary E. Schenley, whose gifts to the city amount to about ten million dollars, that the great need has been supplied. Schenley Park is situated accessibly, and consists of seven hundred and fifty acres. The topography lends itself admirably to landscape gardening. Nobler or finer trees can not be found anywhere, and the bold hills, small streams and deep valleys have been made use of in an artistic way. Highland Park lies on the hills overlooking the Allegheny River, in the northeast environs of the city. The carrying out of the artist's plans has caused the construction of winding shady drives; and the features include an artificial body of water known as Lake Carnegie. Reservoirs which supply the eastern division of the city with water are located



The Carnegie Institute.

on the high hills adjacent. The total area of all of the parks is over nine hundred acres.

The city that leads the world in iron manufacture must inevitably be a smoky city. For a period beginning in the early eighties, when natural gas was first applied to manufacturing on a considerable scale, the diminished use of coal led to brighter and clearer conditions. But the industrial growth of Pittsburgh has been such that the supply of gas soon came to be inadequate. Gas is still used as an auxiliary fuel, but the percentage of soft coal is growing relatively larger year by year. So far as the iron furnaces are concerned, it is hardly to be expected that much relief from smoke is likely to be had while coal remains as plentiful and cheap as now. (It has been estimated that the Pittsburgh deposits are likely to last two hundred years or more, according to the rate of increase in production.)

But the most of the furnaces are situated outside of the city proper, and the annoyance of smoke and soot from the steel and iron works is less than is generally supposed. Many visitors express surprise over the small amount of smoke, as compared with what was expected; and it is not unusual to hear it said that Pittsburgh is not perceptibly smokier than many other places.

But the Pittsburgher makes no such claim. The Iron City is blacker and more smoky than most towns; although it is certainly not so bad as its reputation. And it is going to be very much better. For years those of her citizens interested in civic improvement have been fighting for a smoke ordinance; and now one has been carried through—a good one, which will stand: it has been framed upon corrective and improved lines. The people have learned through hard experience how to do some things effectively. Establishments that have for years taken advantage of Pittsburgh's sooty reputation, and so allowed their chimneys to belch incontinently, are already being restrained.

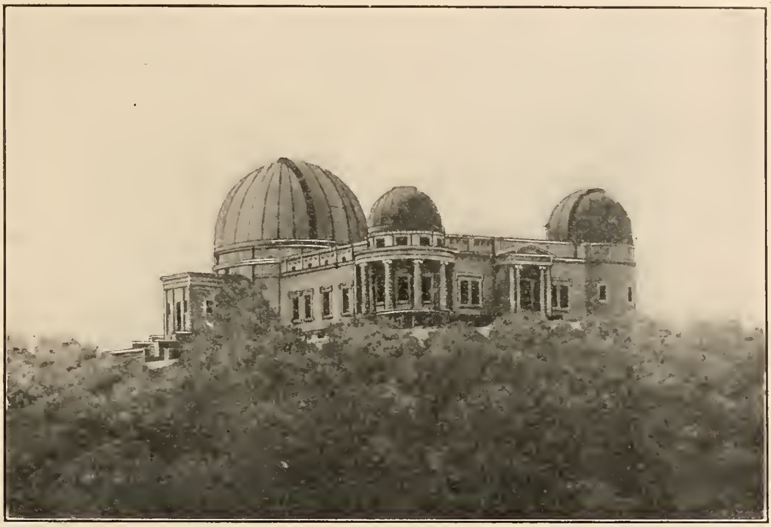
Compared with many large manufacturing cities, the physical conditions in Pittsburgh do not render it an especially undesirable place of residence; and a little journey through the East End divisions of Oakland, East Liberty or Swissvale would convince almost any person who views the miles of handsome residences and well-kept grounds. And the surroundings and suburbs extending for miles down the Ohio River are quite unusually beautiful. Moreover, contrary to a supposition which prevails in other places, Pittsburgh is not unhealthful. According to the statistics, Allegheny County will bear comparison in healthfulness with almost any of the larger centers of population.

Architecturally, there is much that can be said for Pittsburgh, as compared with other cities of equal prominence; and a good deal has been written thereon. The Allegheny County Court House stands

The Carnegie Technical School.

as one of Richardson's masterpieces; and among the noteworthy structures are the new Carnegie Institute, the Technical Schools, quite a number of imposing and beautiful churches and the Nixon Theater—regarded as among the beautiful and artistic amusement places of the country. Choosing from among Pittsburgh's extraordinary number of modern skyscraper business edifices, it may doubtless be said with truth that the Frick Building is the finest of its kind anywhere.

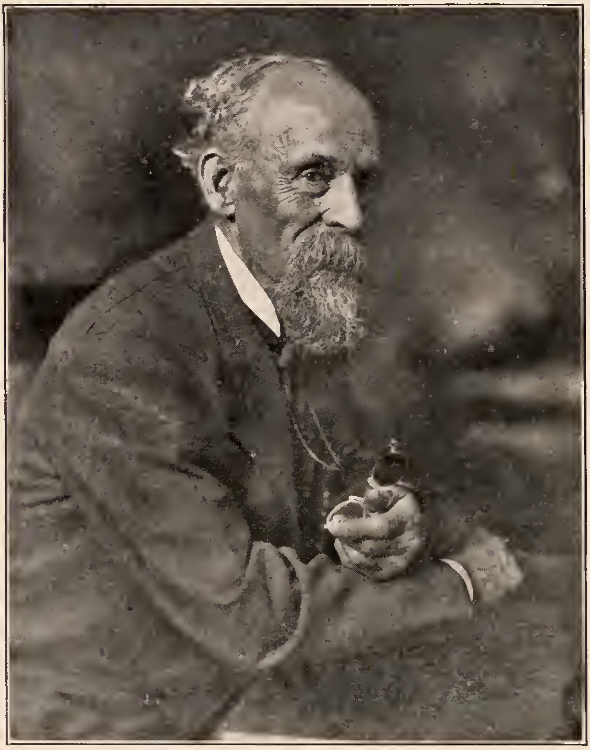
There is one feature that seems especially worthy of note. In no part of the city, practically speaking, are there *rows* of dwelling houses



Allegheny Observatory.

built closely together—each house looking exactly like its neighbor. Possibly the city's sponsors remembered the experience of Glasgow, whence many examples and traditions were naturally derived. There the evils of overcrowding bore their ill fruit until some time in the sixties, when a great change was enforced. The inestimable benefit of wider spaces between residences should naturally have offered its lesson. At least, the builders of Pittsburgh knew—and profited from the knowledge.

The tenement districts must still be spoken of apologetically, for there are portions of Pittsburgh where the dwelling houses of the poor and working classes are decidedly bad. But the city is no worse than many others in this respect; and, moreover, Pittsburgh's fame as the great industrial paradise has caused an influx of laboring classes which no amount of intelligent study could have forestalled. As to general cleanliness there is much to be hoped for, and expected. Not all of the sections of the city are as well kept as they should be; but nobody doubts that conditions are to be improved in the near future.



Doctor John A. Brashear.

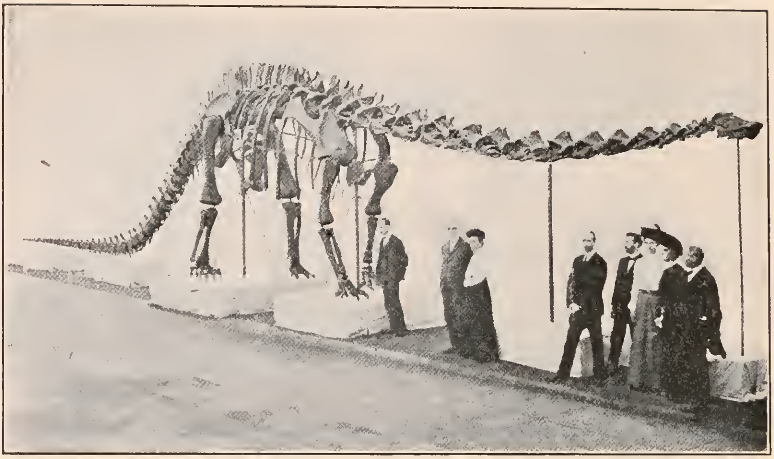
The main business streets and the finer residential portions of the city are kept in as good condition as almost anywhere else.

Thus far the reference has been to the physical and industrial aspects. There are other elements worthy of note; lines of broader development in which Pittsburgh has already attracted attention: wherein she promises to exert, some day, an influence over a wide area. These fields are represented by the Art Society, the Scientific Museum, the Pittsburgh Orchestra, the Public Library System, the Technical Schools, and the Astrophysical Observatory affiliated with the Western University of Pennsylvania. One distinction must be named. the observatory represents a field that has long since "arrived." Its work is known to science the world over.

The Pittsburgh Art Society was born in 1873; and out of that society of thirty-five years ago have been developed the Carnegie Art Galleries and the Pittsburgh Orchestra. The Museum, the Art Galleries and the Technical School are several parts of the Carnegie Institute, toward the upbuilding of which, together with the library, Andrew Carnegie has given many millions of dollars. The orchestra is a separate entity, now self-supporting.

In the cultivation of the fine arts, the Art Department of the Carnegie Institute has unquestionably given to Pittsburgh a great stimulus. The galleries contain a fine permanent collection of paintings and sculpture, the property of the institute, as well as numerous paintings which have been loaned by private owners for an indefinite period. This exhibit is open to the public daily during the greater part of the year, and no charge for admission is made. Each year the department holds a competitive exhibition of paintings, which is open to the artists of the world; and these exhibitions have become of international importance. Hundreds of paintings are sent by noted artists of Europe and America; the efforts of the directors tending toward the elimination of favoritism, and the fostering of a spirit of fairness. This broad policy of the Art Society is influencing the artistic spirit at home and abroad. The children of the public schools are encouraged to interest themselves in the art exhibits; and art talks are given by the director to classes of children from the schools. Incidentally, Pittsburgh has in the past contributed a few names to the world of art. In the list of

Samuel Pierpont Langley.



Diplodocus Carnegiei Hatcher; Order of Dinosauria: in Carnegie Museum; 84 feet in length; found by the Carnegie Expedition under John Bell Hatcher, in Jurassic beds, Sheep Creek Basin, Wyoming, in 1900. The only complete specimen ever found.—A *replica* is in the British Museum.

eminent artists who have lived in the city are John W. Alexander, Charles S. Reinhart, A. G. Reinhart, George Hetzel, William, Alfred and Bryan Wall, Clarence Johns, David Blythe and others.

The new institute building, usually so called, is an Italian Renaissance structure covering four acres, and containing the Library, the Museum, the Fine Arts galleries, and the Hall of Music. The Technical Schools have another location. The museum has over 100,000 square feet of floor space on the first, second and third stories; and a special library which takes up one end of the great central court. In the basement are rooms devoted to the curator's work, and the preparation of specimens. The lecture hall seating between six and seven hundred people opens from the museum section; and here the Academy of Science and Art holds meetings, and provides lectures which are free to the public. At present there are in the museum over 1,300,000 objects on exhibition. The aim is to not only illustrate and interest, but to educate the masses in matters of fauna and flora, geology and mineralogy. Research and science are furthered by the systematic collections in its library.

In the field of music, the Pittsburgh Orchestra has achieved national distinction—going back to the earlier days when Frederic Archer was its first conductor. Mr. Archer also played the magnificent organ for many years. When he died Edwin H. Lemare became organist; while the directorship was taken up by Victor Herbert. Under Herbert the orchestra became famous as one of the leading musical institutions of the country; and under Emil Paur, the present conductor, whose reputation is international, it has reached a still higher level. The concerts are always well attended, although they are not free. A series is given in Pittsburgh every year; and usually a tour is made of the larger cities. Twice a week during a large portion of the year free organ recitals are given in the music hall of the institute. Taken for all in all the Pittsburgh orchestra is doubtless exercising a rather broad influence in musical matters. Every year there is a season of grand opera, which is always popular. As a rule the churches have excellent choirs, and many have talented organists.

The library (reference here is to the Pittsburgh Library distinctively, since there is also a fine Carnegie Library across the river on the north side—formerly Allegheny) has found as wide and excellent a field of influence, perhaps, as has almost any institution of the kind anywhere. The plan was developed by Librarian Edwin H. Anderson, who was its head from 1895 to 1905, and embraces among many features the furnishing of collections of books to the public schools and to the vacation and summer schools; the establishment of numerous branches in large centers of population; the Home Libraries department for children; and a liberal encouragement of the use of library books by all classes of people. The encouragement has been particularly directed toward the laboring classes and poorer people. This work has reached an unusual degree of appreciation. The library has (1907) 300,000 volumes; and a few figures relating to the book circulation may be of interest. The present home circulation (that is, books taken out to carry into the homes of the people) is more than 800,000. The entire recorded use of books from the library in 1907

Palm Room, Phipps Conservatory, Schenley Park.

Skyline of Pittsburgh.

was 1,463,207. Of the entire withdrawals from the library, the percentage of fiction to the whole was less than 58 per cent. It is stated by the librarian, Mr. Hopkins, that the withdrawals in 1908 will probably exceed two millions. The Boston Public Library had, last year, a total of 903,349 books. In 1907 the report of the Boston Library showed a home circulation of 1,461,403. The report states that of this number 70 per cent. "very nearly" of the entire withdrawals was fiction: including juvenile books, the percentage of fiction was much greater. These comparative figures are worth considering, since they indicate the importance to the community of the work of the Pittsburgh Library. It would perhaps hardly have been supposed that the relative proportion of *useful* books, namely, works of science, history, travel, philosophy, art, biography and religion, which are being read in a community composed so largely of workers in the industrial trades, exceeds the showing of the Boston Library by 12 per cent.

The Carnegie Technical Schools were established in October, 1905; and they have a present endowment of four million dollars. There are four schools: for engineers; artists and designers; tradesmen; and women; and their development has been according as space could be made ready. At present the accommodations are not adequate; but when the fine and commodious School of Applied Science is finished, next September, it is anticipated that the present departments will all be adequately housed. As time passes, buildings will be erected as necessities demand and funds permit. The statement is made that the buildings now provided equal not more than one seventh of the future's needs. The number of students at present, in all departments, is 1,750. They come from thirty states; and it is reasonably anticipated that the schools are going to draw from all quarters of the world. The growth is very rapid, in appreciation and interest.

The School of Engineering comprises electrical, mechanical, civil, metallurgical and chemical; while under architectural, a department is maintained by itself. The School of Design is virtually that of architectural design.

The trade courses embrace draughting, electrical wiring, plumbing, bricklaying, sheet metal and cornice work. (In one of the lofty rooms of this department a complete two-story house is in course of construction, wherein all of the technical features of electrical wiring and equipment, plumbing, drainage, etc., are carefully demonstrated.) The trade courses also involve foundry practise, forging, pattern making; machine-shop practise; house and sign painting.

The Women's School comprises technical courses for the daytime; and trade courses in the night schools. In the technical courses are mathematics, English history, social ethics, chemistry, drawing and designing. Also, departments of dressmaking and millinery are included. There is a special department intended for professional housekeepers, matrons and hospital managers, with professional courses in these lines.

The night school for women comprises purely trade courses, aiming to make the services of women more valuable. These courses embrace bookkeeping, stenography, typewriting, cooking, dressmaking. Those

Sixth Avenue Churches and Skyscrapers.

who take up stenography must study commercial law; and those who study cooking must take instruction in the chemistry of foods.

It is the aim of the institution as a whole to keep abreast of all matters of technical science. The faculty has been most carefully selected; and the determination is to get men practical experience—

men who know what to go after and how to obtain and present the most valuable kind of knowledge. There is one main purpose, differing from any that has hitherto been tried: the length of the course is indeterminate. The argument given is, the impossibility in a collection of students to have all equally trained or equally efficient within a given time. Each student must, in a sense, be the arbiter of his own destiny: he must get a certain work done before he obtains his certificate. If he fails to do this, he is given instead a statement to the effect that whereas he has been in the institution a certain number of years, he has merely covered a certain ground creditably. The certificate still awaits his future efforts and accomplishment.

Everything is done to bring the advantages and resources of the schools within reach of the plain people. In other words, it goes down

Pittsburgh in 1817.

to them, and after them. The type that it is designed to reach is the middle-class boy. There are some boys of wealthy parents in the schools; and doubtless there will continue to be a certain percentage always; but he is not the type. The theory is that the country boy or the son of poor parents is going to bear the future load in technical and industrial life. It is also recognized that it is from these strata that the best results are sure to come—that the young man who has had the hardest struggle, to whom life presents the greatest problems and the most toil and effort, is the coming man. He is far more certain to achieve success and a name. Great emphasis is laid on the personality of the student: he must have the proper attitude toward work; he must be active, bright, always industrious, and never slovenly in his work.

The intention of the school is to have its heads composed of men whom the students will seek from afar. The members of the faculty shall be men sought by students from everywhere, for sake even of the one man.

The feeling of democracy is cultivated; and every discouragement possible is thrown in the way of dividing into high and low castes, upper and lower strata, cliques or classes.

The tuition fee is nominal. The directors wish it understood that while the school gives courses in engineering and the trades which are on an equal footing with other institutions, yet it is not the aim to turn out skilled or practised engineers or mechanics. What is claimed is that the institution can turn out those who are *capable of becoming* better engineers and mechanics than those who have lesser opportunities, or training not so good. That which only can develop the mature engineer or mechanic is future practical experience.

Another aim of the institution, already very effective, is the finding of employment to aid indigent students in working their way through. It is not claimed that employment is provided for every student who now applies for it; but that much is being done, and much more will be done in the future. During 1907 over 600 men students applied for employment through the secretary of the schools. Approximately 350 positions were offered, and nearly 300 positions were filled by students, making up an aggregate earning capacity of upwards of $25,000.

The Western University of Pennsylvania is, with one exception (the University of Nashville), the oldest institution of learning west of the Appalachian Mountain ranges. It has an enrollment to-day of somewhat more than 1,100 students; and besides the Department of Astrophysics (of which, more hereafter) there are five main departments, namely: Engineering, Law, Medicine, Pharmacy and Dentistry. The buildings are now scattered; but the plans for the future involve the concentration of all departments on a new site. The location is most admirable, consisting of 43 acres adjacent to the Carnegie Institute, and the Technical Schools. A race for development seems not unlikely to grow up between this institution and the Technical Schools, both of which seem destined to become strong educational factors.

It was in the year 1867 that Samuel Pierpont Langley was appointed to the chair of astronomy and physics in the Western University of Pennsylvania; and beginning almost from that time the Allegheny Observatory has held a place among the working observatories of the world. The equipment contained only a thirteen-inch equatorial telescope; and necessity, then as always the greatest spur to progress, stimulated Langley's fertile brain for a means of providing his observatory with better apparatus. For some years he labored with the problem of electrical time signals for railroads, in which he was finally successful, introducing the time signals on the Pennsylvania system, and other railroads in the district. Since then observatory time has been supplied from various observatories to nearly all railroads. Returning after a number of solar eclipse expeditions, Langley began, about 1870 to study solar phenomena, in which he became one of the highest authorities, proving, among other things, that the absorption by the earth's atmosphere of solar heat is variable, and that sunspots have no appreciable effect upon the temperature of the earth. In 1885 he gave the results of some of his investigations in solar phenomena before the Royal Society in London. During his charge of the Allegheny Observatory he contributed upwards of a hundred papers to scientific journals. In his studies of solar physics, recognizing that the instruments were inadequate to record much of the sun's radiant

ENTRANCE TO HIGHLAND PARK.

energy, he began a long series of experiments which resulted in the invention of that marvelously delicate instrument, the bolometer. With this perfected, he renewed his investigations of the sun, moon and stars, which brought to light facts as important as any in the whole realm of astronomical physics.

Beginning with Langley's charge of the observatory there had grown up a valuable and intimate association with John A. Brashear, which continued after Langley's transference to the Smithsonian Institution, and until his death. The bolometer could not have achieved its wonderful success without Brashear's mechanical and scientific assistance. Experiments had shown that transparent crystals of rock-salt have the faculty of transmitting the low heat rays of the sun (that is, the invisible rays below the red); and Brashear undertook the solution of the problem of producing accurate surfaces upon lenses and prisms made of this substance. Its deliquescent character was a factor very difficult to contend with, but a method was discovered by which surfaces were produced within a half light wave, answering to the most critical demands of Langley's bolometric research. During a visit to the Chicago World's fair, in 1893, some unusually fine rock-salt crystals from mines in Poland were found in the Russian exhibit, which were secured for the Smithsonian Institution, from which some of the largest and finest lenses and prisms were made. Langley's joy in

Smithfield Street

Brashear's success was boundless—and naturally so. The proportion of invisible radiated heat, underneath the red part of the sun, is many times greater than the visible rays. It is through the curious quality of rock-salt lenses and prisms that it became possible to concentrate the dark, lower heat rays, and to achieve the splendid results with the bolometer.

Professor Langley's life work and the honors that have been heaped upon him are so well known that to enumerate them would be supererogatory. The secretaryship of the Smithsonian Institution is the highest gift of science in America, and this honor he held for nearly twenty years, until his death in 1906. He was given the Rumford Medal of the London Royal Society, and elected to a membership in that body; was president of the American Association for the Advancement of Science, besides having other honorary memberships and degrees in large number.

John A. Brashear began to make telescopes as a business in 1880; although his first telescope, a refractor of five-inch aperture, was made in 1872–5. When it is remembered that Brashear had reached middle life before he relinquished his employment as master mechanic in the rolling mills to begin experimenting in the field of optics and astronomy, the amount of valuable scientific work he has accomplished in the thirty-odd subsequent years is fairly amazing. He made many pieces of apparatus for Professor Langley's studies; besides a long list, impossible to enumerate here, of telescopes, reflecting lenses, mirrors and spectroscopes for astronomers' use in all parts of the world. He has sent instruments to England, Ireland, France, Germany, Egypt, South Africa, Australia, Syria, Italy, Argentina, Japan and numerous other countries, besides an endless series of apparatus for use in the United States and Canada. One reflecting telescope which he himself used in a three years' study of the floor of the lunar crater Plato, was in constant use afterwards by Professor Langley. Brashear developed a highly valuable method of silvering mirrors, which was freely given to the scientific world; published a paper on "A New Method of Correcting Errors of Curvature in Optical Surfaces," which has proved invaluable; constructed apparatus for measuring the velocity of light, and also to measure the differential velocities between long and short waves; many refractometers, and optical trains—among which were two for Lord Rayleigh with error not exceeding 1/1,500,000 of an inch. He constructed the first spectro-photoheliograph for Professor Hale, a work that was epoch-making in the realm of solar photography. One of his spectroscopes made for Professor James E. Keeler, of Allegheny Observatory, was the instrument used by Keeler in the discovery of the physical character of the rings of Saturn, proving the correctness of the Clark Maxwell mathematical theory. One of his finest instruments is the Mills spectrograph for the Lick Observatory, used by Professor Campbell in his many discoveries of the motions of stars in the line of sight. With the cameras he has built for astronomical photography a hundred new planetoids have been discovered. He has made, perhaps, the largest perfect plane in existence, 33-inch diameter. He has just completed the 37½-inch mirror of the great Cassegrain telescope for the University of Michigan; and is now constructing a 30-inch refractor for the Allegheny Observatory and a 24-inch for Swarthmore; and has orders for enough large and important instruments to tax the capacity of his workshop for more than two years.

Data about the hundreds of pieces of apparatus that he has made would fill a book. And besides, he has raised by his own personal efforts nearly three hundred thousand dollars for the construction of the new astrophysical observatory of the Western University of Pennsylvania—the equal of any in the world. "I can not say," he says, "that the bank balance bears a fair relation to the work we have done," but he adds that in view of the marvelous discoveries made, and the appreciative and kind treatment he has had from the world, he feels like saying, "I am content. . . . I have that which can not be bought by dollars and cents." Dr. Brashear always emphasizes that his associate and son-in-law, James B. McDowell, is master of the development of the delicate work in optical service; and that he could never have made his success without McDowell's cooperation. Dr. Charles S. Hastings, of Yale University has also been associated with Dr. Brashear in the development of the mathematical problems of modern optics: the day of empiricism in optical science having become a thing of the past. Dr. Brashear has twice been a director of the Allegheny Observatory; and is now chairman of the Observatory Committee; he served two and a half years as acting chancellor of the Western University of Pennsylvania. He has degrees of LL.D. from Wooster University of Ohio and Washington-Jefferson Unversity, as well as degree of Sc.D. from the Western University.

Pittsburgh's "arrogance and greed" have been so advertised that it should be permissible to mention that the city contains more than one hundred and fifty active benevolent and charitable institutions; more than twenty large, finely equipped hospitals; and over four hundred churches of all denominations. It is scarcely more of an iron city than a city of churches and church-going people. There are benevolent societies, non-sectarian and sectarian; homes for the destitute, aged, infirm, white and colored, for men, women, girls and children; public baths for the poor; children's playgrounds for poor children.

One of the most notable institutions (undoubtedly the most remarkable single-handed permanent beneficence in the world) is the Carnegie Relief Fund, endowed five years ago by Andrew Carnegie, with a gift of four million dollars in Steel Company bonds. This fund applies to more than 65,000 men employed in the iron and steel trades, who, with their families and dependents, would comprise an aggregate population of over 300,000 persons. The bonds bear good interest, and the income provides for accidents, deaths and pensions. There has been a total disbursement already of $1,129,117.29. In 1907 the amount paid out was $216,764.03.

A well-known writer has said that Pittsburgh men are strong, upright and good intentioned, but "too busy" in the upbuilding of industries and fortunes to pay attention to the civic welfare. Perhaps the utterance was timely; for since then the long-delayed civic awakening has come to pass. The betterment, always hoped for—regarded by the many as impossibly Utopian, but always fought for by a tenacious and stubborn few—is an accomplished and positive fact. Two years ago the fighting citizens seized a political opportunity; and Pittsburgh has in Mayor George W. Guthrie an executive of whom it is justly proud. Not even by his bitter political opponents is he charged with any wish or motive that is foreign to the highest interest of the city. From a machine-ridden, ring-encircled municipality, the revolutionizing and purging have been so thorough that political corruption is now virtually non-existent. It is no longer "a city ashamed"; it is joyful and proud.

Anxious critics have inquired whether Pittsburgh's sudden and untoward opulence is a menace—a menace to itself, and to humanity. The city has been adding a chapter or two to the history of sociology. It has turned out (*promoted* is perhaps more accurate) a new and curious variety of plutocrat; and still worse, has produced a new leisure class. The latter was born out of the loins of toiling industry; has sprung upon an amazed world within a decade; and the funny twins have made an unwelcome commotion. It is seriously asked whether these do not furnish a gauge by which the future manhood of Pittsburgh is to be determined: whether they are not the prolific seeds of complete degeneracy.

The answer is to be found in the fact that Pittsburgh was raised up by the brain and brawn, the self-respecting moral qualities of its Scotch-Irish founders. They were, and are yet, a forceful race—fighters and workers, natural leaders, men with a high sense of duty, who do their own thinking. Do the critics see no signs of the vital undercurrent which is to be the determining factor of the future? Do they not see in Pittsburgh's intellectual activity a guaranty of the more wonderful reputation which is to be achieved hereafter, when the present spendthrift perversions and pranks have been long forgotten? Just as it has been in the past, so now the vicious idler is made to feel uncomfortable. His father toiled for his winnings, is toiling yet, if he lives, and the son who lives only to spend money and invent new and outrageous forms of diversion is a virtual outcast. And yet he is an almost inevitable outgrowth of the marvelous period. He is not confined to Pittsburgh; but has merely been somewhat disproportionately advertised. And doubtless, too, his number is small as compared with what it might have been had the principles of his progenitors been less firmly anchored. He will not increase. Pittsburgh has even a confident hope that he and his tribe may become extinct.

THE EDUCATION OF THE COLORED RACE IS THE DUTY OF THE NATION

By Professor HARRIS HANCOCK
UNIVERSITY OF CINCINNATI

FORTY years ago the civil war was ended, the negro freed. Individually there will always be persons who entertain feelings of animosity against their fellow man of another section; for sectionalism will ever exist. But as a nation such feelings must be buried, if there are any which influence the political government of the people. For every section is a part of the nation and the nation is under equal obligations to every section. Each state is an integral part of the nation, and no state may be regarded by the union as a province.

It is a historical fact that slavery was forced upon this country by England against the protests of the states, both north and south. For example, in 1769 the House of Burgesses of Virginia by a vote *abolished slavery,* but was prohibited from so doing by George III., King of England, "in the interests of commerce." Further, in 1778 Virginia, and in 1798 Georgia, passed acts prohibiting the importation of slaves, Virginia fixing as a penalty the heavy fine of one thousand pounds; it is also true that Virginia, Tennessee and Kentucky were banded together in the support of a practical system of emancipating the slaves by degrees, a movement which was eventually stopped by the abolitionists, a party that came into existence after the Missouri compromise, in 1820–21. This party demanded the immediate and uncompensated freedom of all slaves, notwithstanding the fact that England had just liberated four hundred thousand slaves at the cost of twenty million pounds. No other such attack upon private property can be found in the history of civilized nations. We emphasize the fact that some of the southern states led the world in an earnest appeal to prevent slavery, although with a peculiar irony the world to-day holds the south responsible absolutely for the existence of this institution. And further to show that the nation as a whole was responsible for the existence of the colored race in America, it must be recognized that although the south was at that time somewhat of a maritime people, *no slave was ever brought to this country by a southern vessel,* and that "New England ship-owners practically monopolized the traffic of slavery for a number of years."[1] It is also found that Massachusetts was the first colonial state (1641) that legalized slave

[1] See "The True Civil War," pp. 28, 29, 30; and in this connection see also "Origin of the Late War," by George Lunt, an eminent lawyer of Massachusetts.

traffic in America. Slavery existed at the north, as long as it was found profitable, and throughout the nation slaves were regarded as "property." This was a heritage handed down to us from England, in which country a law was enacted in 1713, the venerable Holt presiding, that held slaves to be "merchandise."

Thus the presence of the negro slaves in America was legally established by the courts of England and was for the most part effected through vessels of New England. Being more profitable in the south, they were soon gathered together there in great numbers.

It is not the purpose of the writer to go into the causes of the civil war, to consider which side was right, which wrong, or whether either side was either right or wrong. He believes that historians of the future will agree with Mr. Lunt when he says: "Self-seeking and ambitious demagogues, the pest of republics, disturbed the equilibrium, and were able at length to plunge this country into the worst of all calamities—civil war. The question of morals had as little as possible to do with the result."

The advocates of emancipation always declared that *the fate of the colored man was a responsibility of the whole nation.* This doctrine was accepted as a fact by the United States government and the colored man was eventually freed. But having accepted the responsibility of this race, *it is and always has been the duty of the whole nation to care for the improvement and education of the colored man.* His up-building, however, has been left entirely to the charge of the south, which consequently has had to assume the task of "educating two races out of the poverty of one."

It may be noted here that the national census shows that from 1860 to 1870 the assessed value of southern property diminished by practically one half, while the increase in northern property was approximately multiplied by two. And upon this basis the northern states by means of the protective tariff and other legislations have increased in wealth far more rapidly than those parts of the country which are primarily agricultural.

The disparity that is thereby produced in the funds for the education of the children in the different sections at the present time is seen from the following statement: The average amount spent in the United States at large is—per capita of the pupils in average attendance—$21.38; in the western states the average expenditure is $31.59, while for such states as Alabama and the Carolinas this expenditure is approximately $4.50. These figures are given by Mr. Murphy in an address delivered before the General Session of the National Education Association, Boston, July 10, 1903. In this address Mr. Murphy says:[2] "A democracy which imposes an equal distribution of

[2] *Cf.* also Murphy, "The Present South," p. 42.

political obligations must find some way to afford a more equal distribution of educational opportunities."

The urgent needs of better educational facilities in the south are at once apparent from the following statement:

The illiteracy of the native white population (meaning those who can neither read nor write) ranges from 8.6 per cent. in Florida, 8 per cent. in Mississippi and 6.1 per cent. in Texas to 17.3 per cent. in Louisiana and 19.5 in North Carolina; as contrasted with 0.8 per cent. in Nebraska, 1.3 per cent. in Kansas, 2.1 per cent. in Illinois, 1.2 per cent. in New York and 0.8 per cent. in Massachusetts. In all the states taken outside the southern states and forming a group, the average rate of illiteracy among the native white population is only 2.8 per cent. as against 12.2 per cent. of native white illiterates in the south.

According to the figures of Dr. Charles W. Dabney,[3] there are 3,500,000 people in the south ten years of age and over, who can not read and write, of these about 50 per cent. of the colored population and 12.5 per cent. of the white.

In 1900, the states south of the Potomac and east of the Mississippi contained in round numbers 16,400,000 people, of whom there were 10,400,000 white and 6,000,000 black.

In these states there are 3,981,000 white children from five to twenty years old and 2,420,000 black children of the same age, making a total of 6,401,000 children to be educated.

These are distributed among the states as follows (see the above-mentioned report):

	White.	Colored.	Total.
Virginia	436,000	269,000	705,000
West Virginia	342,000	12,000	354,000
North Carolina	491,000	263,000	754,000
South Carolina	218,000	342,000	560,000
Georgia	458,000	428,000	886,000
Florida	110,000	87,000	197,000
Alabama	390,000	340,000	730,000
Mississippi	253,000	380,000	633,000
Tennessee	590,000	191,000	781,000
Kentucky	693,000	105,000	798,000
Total	3,981,000	2,420,000	6,398,000
Arkansas	381,000	149,000	530,000
Louisiana	277,000	262,000	539,000
Texas	956,000	260,000	1,216,000

Only 60 per cent. of these children were enrolled in the schools in 1900 and the average daily attendance was only 70 per cent. of those enrolled; so that only *42 per cent. of the southern children are*

[3] See Report of the Proceedings of the Sixth Conference for Education in the South.

actually at school. One half of the negroes get no schooling whatever and one white child in five is left wholly illiterate.

In North Carolina the average citizen gets only .... 2.6 years' schooling.
In South Carolina the average citizen gets only .... 2.5 years' schooling.
In Alabama the average citizen gets only .... 2.4 years' schooling.

In the whole south the average citizen gets only three years' schooling. *And what sort of schooling is it?* The answer may be inferred from what is found elsewhere in this discussion.

In North Carolina the average value of school property is $180
In South Carolina the average value of school property is 175
In Georgia the average value of school property is 523
In Alabama the average value of school property is 512
The average monthly salary of a teacher in North Carolina is $23.36
The average monthly salary of a teacher in South Carolina is 23.20
The average monthly salary of a teacher in Georgia is 27.00
The average monthly salary of a teacher in Alabama is 27.50
The schools of North Carolina are open on an average of 70.8 days per year.
The schools of South Carolina are open on an average of 88.4 days per year.
The schools of Georgia are open on an average of ..... 112.0 days per year.
The average expenditure per pupil in average attendance is $4.54 per annum in North Carolina.
The average expenditure per pupil in average attendance is $4.44 per annum in South Carolina.
The average expenditure per pupil in average attendance is $6.64 per annum in Georgia.
The average expenditure per pupil in average attendance is $4.50 per annum in Alabama.

In other words, in these states in schoolhouses costing an average of $276 each, under teachers receiving an average salary of $25 per month, we have been giving the children in actual attendance five cents' worth of education a day for 87 days only in the year.[4]

These figures, compared with those indicating like expenditures in the other states of the union, show that the expenditures in those states are from four to six times as great as in the south.

Mr. Geo. S. Dickinson of New Haven, Conn., one of the best informed students of southern conditions,[5] says:

There is no end of bounty bestowed on institutions for the common people in the northern cities. Why, as an American, should I be more interested in the children of Boston or of New Haven than in those of the Carolinas and Georgia? Who are the children of Boston? Sixty-seven per cent. of them are of parentage from beyond the seas. Eighty per cent. of the children of New York are of such parentage, and the story is the same for the other great cities—Cleveland, Chicago, San Francisco. More than three quarters of their people are of foreign antecedents: Irish, Germans, French, Italians, Hungarians, Poles, Armenians, Chinese, Russians, etc.

[4] Chas. W. Dabney, *loc. cit.*

[5] *Cf.* also statistics given by him in Chap. XVIII. of Vol. I. of the Report of the U. S. Commissioner of Education for 1902 and also the *Southern Workman*, January, 1903.

Not that I would disparage the beneficent ministries of education for any of these. It is an occasion of joy. I only speak of what we are doing for them to emphasize what we ought to do for those of our own blood. It was the apostle to the gentiles engaged with all his might in efforts for the people of other races, who wrote: "If any provideth not for his own, and especially his own household, he hath denied the faith and is worse than infidel." And so, to-day, our interest in other people should deepen our sense of responsibility for those who are nearest of kin.

Who are these 10,000,000 whites of the south? They are the children of the colonial pioneers, of the soldiers who made the continental army, of the fathers who established the republic. They are many of them descendants from a New England ancestor as well as from settlers of Virginia and the Carolinas. A cursory study of the subject leads me to believe that in some counties of Georgia a larger proportion of the people can trace back through some line to a New England sire than in the city of Boston. The cracker is of the same blood as the merchant prince. This is to be seen in their very names. The people of the north and south are one, in feature and in native force, cherishing common religious beliefs and conserving the immemorial traditions of freedom and independence.

In Alaska the expenditure upon the children of the nation, although sixty per cent. of them are Eskimo, is annually $17.78 per capita of enrolment. Similar provisions are being made for the children of the Filipino, while $4.41 is annually spent[6] upon the student of Alabama, and this too when the people of Alabama are taxed to pay for the education of the Eskimo and Filipino.

We make no criticism regarding the money spent upon the children of our territories. Attention, however, should be called to the fact that our government has already spent more money on the Philippine Islands than would be required to educate our entire negro population for the next fifty years, as is shown by the figures given below. And the United States now considers itself under moral obligation to the civilized world to educate the Filipinos and make them responsible citizens.

The most elementary mathematics applied to the principles of sociology will show that millions of dollars will be required to make of this people a nation comparable to others of the civilized world. Suppose that this result may be achieved, what guaranty is there that the Filipinoes will be our friends and allies in time of trouble, say in the case of a foreign war; or what recompense do we gain from the civilized world for "moral obligations" rendered? Charity begins at home and a nation must consider carefully its *own* ultimate safety and welfare.

We do not claim that the education of the negro is a charity due him by the nation, nor do we wish to consider it a part of friendship of the people of the north to the white people of the south, nor do we hold it a part of philanthropy or a moral obligation to the outside

[6] These figures, of course, vary slightly from year to year.

civilized world. We assert that it is a fundamental duty of the United States government to its own citizenship in the promotion of morality and in the establishment of every department of industry, invention and manufacture which ultimately tends to the improvement, progress and prosperity of the nation as a whole and stands as a bulwark of strength in the time of trouble.

Granting the correctness of statistics already given, every true citizen of the nation will admit that the present conditions existing for the education of southern children must be improved. The writer has ventured to outline a method[7] by which this may be accomplished. It is evident that if the United States government assumes the responsibility of the education of the colored children of the south, the white people, relieved of this burden, will be the better able to meet the educational requirements of their own children.

There are 600 places in the southern states, not counting Virginia, Maryland and Kentucky, which contain 1,000 people or over. In these dwell about 3,000,000 people, white and colored. The other 14,000,000 are country people. This number is over 17,000,000 if the above-named states are added. About 10,000,000 of these are native white Americans with 3,500,000 children to be educated; and there are seven millions of colored people with 2,500,000 children to be educated.

The area of this country is seen in the following table:

	Square Miles.
Virginia	42,450
North Carolina	52,250
South Carolina	30,570
Georgia	59,470
Florida	58,680
Alabama	52,250
Mississippi	46,810
Louisiana	48,720
Arkansas	53,850
Tennessee	42,050
Total	487,100
Kentucky	40,400
Texas	265,780
West Virginia	24,780
Maryland	12,210

Owing to the small proportion of colored people with respect to the total population in Kentucky and West Virginia and the small proportion of them in comparison with the great area of Texas, these states are omitted from the present calculations. Other appropria-

[7] This method must be regarded as merely provisional. It is intended for the most part to give an idea of the expenses necessary for an adequate education of the colored race.

tions may be made for these states as are found necessary after the proposed system of education has been put into operation in the states where the great masses of negro population are found. Counting Maryland, there are practically 500,000 square miles of this country that are densely populated with colored people.

One schoolhouse for each sixteen square miles would make the average distance about a mile that each child would have to walk. In no case would this distance be as great as three miles. This is seen by forming a square, each side being four miles, and by placing the school house in the center of the square. These buildings, however, may be placed nearer together or farther apart according to the density of the population.

A schoolhouse with grounds may be secured for $500, which property may be kept in repairs with funds mentioned later. Teachers in most localities may be readily secured at $40 per month and six days per week, so that the expenditure below may be regarded as quite sufficient.

A teacher at $50 per month for ten months—$500. His time may be divided between two schoolhouses, he teaching five months at the one and five months at the other, or he might teach alternate days at either schoolhouse, in which case he should live about halfway between the two. In the latter case, which seems preferable, the pupil has less time to forget what he has already acquired and besides he may be of considerable service to his parents.[8]

Beginning at eight years old, the child should be required to attend school six years. If it attends school a longer time, payments for the same should be made. This money may be used to help in part to keep the schoolhouse in repairs.

About thirty thousand schoolhouses are necessary for the above area of territory. These houses would require an initial expenditure of $15,000,000. All of this sum need not be used at one time, as it will take several years for the consummation of the system and in the building of the houses. The yearly expenditure for the thirty thousand teachers, fuel, etc., at say $250 per house is $7,500,000. This is about the cost of one battleship.

In the six years of primary study these children may learn good behavior, discipline, reading, writing, arithmetic, geography, spelling, elementary grammar, elementary history, something about farming. The average pupil in the primary school will for ages to come be more adapted to working the land than for any other occupation. The ex-

[8] A successful system is in operation in the University of Cincinnati among some of the engineering students, who spend alternate weeks at the university and at their employers' factories. These students are thus able in six years to earn their way through the engineering course.

ceptional scholar (and there will be about one in thirty) should be given an opportunity at the higher schools of becoming teachers, preachers, doctors, shoemakers, wheelwrights, etc. They should also be fitted to fill the better positions in manufacturing and mining establishments. Before entering these higher institutions the pupil should be made to pass satisfactory matriculation examinations and it should be shown that he is of good character.

Such schools as Hampton and Tuskegee may be established in each of the southern states. In them industrial education should be especially emphasized, and the training of preachers, doctors and teachers (who wish to teach in the lower schools) should be provided for. These schools will be for the colored people what the universities are for the white people. They may be supported through taxation of the negro property and through the munificence of philanthropists interested in the colored race. About one fifteenth of the school money expended now is derived from taxation of negro property. Whether there is a necessity of having colored lawyers for the colored race is a question. There are already institutions in which an exceptionally clever negro may get a legal education. Any legal question may be settled by white lawyers, who for a long time to come will be more skilful in law and consequently the better able to represent their clients in the courts than colored lawyers. Further, I believe the negroes prefer to have their disputes settled by white people. But the teaching of the colored children and in most cases the care of the sick will be left to the colored people.

Whatever education a colored man possesses has been given to him by the people of the south; the present system for his education is due to the people among whom he lives, and this guiding influence must of necessity always be felt.

As shown below, the south is now spending annually at least $4,000,000 towards the education of the colored race. This money has been spent through the direction of the superintendent of public instruction in each state, and its disbursement has been supervised by the superintendents of common schools in the various counties and cities. These men have almost invariably exercised their duties with zeal and honesty. It seems desirable that these officers have charge of the funds for the education of both white and colored children as hitherto has been the case. Their salaries may be somewhat increased so that additional help in the way of secretaries and stenographers may be procured. Thus the expenses for the management of the fund for the education of colored children will be a minimum. The state superintendent should make annual reports of all moneys expended to some head man at Washington.

The office of the Commissioner of Education at Washington has become of such importance that it is an urgent necessity that the head of this office be given a higher rank and be afforded better means of carrying on the great work for which he is responsible. Practically all the great nations of the world have for the discharge of such duties *Departments of Education*, presided over by officers that in this country would correspond to the *Secretary of Education*. At no distant day, the necessity of such an officer must be realized by our government. This officer would have the general management of all such funds as those proposed for the education of the colored race.

It does *not* seem either wise or politic that an ample appropriation once made should ever be increased. As the colored race increases, its capability of earning money should likewise increase, and consequently the taxes on its property should enhance yearly. The corresponding fund available for schools from these taxes should offset the growth of the race. It would be thus effected that the negro race is not entirely dependent upon the federal government for its education, but only in part, this part being relatively less the greater the growth of the population and the corresponding capability of earning money. Thus by the help of the federal government, the negro is given a good chance of making for himself a place in the nation and at the same time he is made dependent upon himself. In the ultimate growth of the nation no people can be expected to assume a responsibility of the education of another people. At the same time the stronger should for a period, say fifty years, lend a helping hand towards the upbuilding of the weaker.

Just as the religion of the white man has been disseminated among the colored people through negro preachers, so must all principles of morality, culture, ethics, etc., be derived from the white race and transmitted to the lower race through the agents of that race. The negro race must be developed along its own line by its own agents as a distinct race and as a separate people. Just as they have their own preachers, they must have their own doctors, their own teachers, etc. These leaders of the people must of necessity gain most of their information from the white man. As all learning is handed down to those in the lower strata of society by those who have reached the higher levels of efficiency, so must the negro ever continue to learn from the white man. That it is the duty as well as the policy of the white man to lend a helping hand no one will deny.

With remarkable foresight, the framers of most of the recent constitutions of the southern states have seen that it was equally a part of justice and to the interest of both races that a representation in the government of political affairs be based not only upon a property qualification, but also upon an educational qualification; and so through legislation they have effected that the upper section of the colored race may enjoy the suffrage while the lower (the poor and illiterate) section of the white race is excluded therefrom. Thereby equal political rights are given to all. The southern states have thus through their own councils put into practise the very ideas that an unbiased writer, the great English political scientist and statesman, the Hon. James Bryce, advocated in his Romanes lecture, delivered at Oxford, June 7, 1902. By putting himself in this upper section, and not before then, can a colored man enjoy all the privileges of an American citizen. It remains that educational facilities be given him to accomplish this end. We claim that it is a primary duty of the federal government to aid the natives of its own states in becoming good citizens and that the "moral obligations" of this country must be first exercised within its own domains.

It has been shown above that the great masses of colored people live in rural districts. The Twelfth Census of the United States, Vol. V., pp. xciii, 4, 127, shows that in 1900 there were 732,362 farms operated by negroes in the south; that 150,000 southern negroes[9] owned their farms and that 28,000 more were part-owners. This shows a marked progress on the part of the negro farmer since the war.

It is clear that a good farmer increases the value of his own farm, and a good farm increases the value of the adjoining farms. Hence country property advances directly as the advance in intelligence of the agricultural laborer, and the advance in the intelligence of this laborer is made directly through the education of his children. Thus education makes labor more effective and thereby enhances the value of all farming lands. Viewed from its moral aspect, statistics have already been collected sufficient to show that the *literate negroes are the least criminal.*[10] It is practically axiomatic that among people closely identified the betterment of one race must also uplift the other, while the deterioration of the one must retard the progress of the other; and that either condition has a direct effect upon the nation at large. The danger of any commonwealth lies not in the education of any one class, but rather in the degeneracy of that class through lack of education; and the peril of the south is not in the rise and progress of the negro, but in his total downfall.[11]

[9] Booker T. Washington (*Tradesman*, Chattanooga, January 1, 1904, p. 99) claims almost double this number.

[10] *Cf.*, for example, Clarence A. Poe, of Raleigh, N. C., in *The Atlantic Monthly*, February, 1904.

[11] It is easy to show the fallacy of an apprehension entertained by some people that *the entire population of this country will eventually be "negroid."* For suppose, as an extreme case, that five per cent. of the colored population were mulattoes (one half black, one half white); *i. e.*, 19 blacks to one mulatto. (The true percentage is much smaller than the one assumed, which makes the hypothesis much in favor of the negroid proposition.) These mulattoes having

We may note the advantage gained by the white people of the south if they are relieved of the education of the colored people:

In the Report of the United States Commissioner of Education, 1899–1900, Vol. II., p. 2501, we find that during the thirty years up to that time, from 1870, the south expended $109,000,000 on the education of the colored people, or say $3,600,000 annually. This money should be added to the educational fund for the white children, and these funds must be gradually increased until they are doubled before these children will have anything like adequate educational advantages.

The average salary of a teacher is not $30 per month, while the average salary of a brickmason is at least double this amount. Further, the facilities that these teachers have had of obtaining knowledge and of equipping themselves for teachers have been very meager, so that many of them are very poorly educated. Hence there is a dearth of knowledge as well as of money in the schools, colleges and even universities. This unfortunate condition must be admitted, when we note that out of a total of $157,000,000 of productive funds held by American colleges, the south has but $15,000,000; the valuation of grounds and buildings of southern colleges is $8,500,000 in a total $146,000,000. The total annual income available for higher education in Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisi-

no social circle of their own cohabit as readily with the pure black as with another mulatto. Hence, *left to themselves,* among every 400 children of the second generation there would probably be:

361 (blacks),
38 (three fourths black, one fourth white),
1 (one half black, one half white);

while among 8,000 children of the third generation there probably will be:

6,859 (blacks),
1,083 (seven eighths black, one eighth white),
57 (three fourths black, one fourth white),
1 (one half black, one half white).

In other words, among 400 children of the second generation, there would probably be one child that has as much white blood in it as there was in its grandmother, and among 8,000 of the third generation there would probably be one as near white as its great-grandmother. *Thus negro returns to negro.*

In a similar manner it is seen that the number of children (three fourths white, and one fourth black) that are born in the second generation from mulatto women (one half black, one half white) is very small; while the number of those that are (seven eighths white, one eighth black) in the third generation born from women (three fourths white, one fourth black) is also small, etc. The ultimate white child is correspondingly rare.

Thus even if illicit sexual intercourse between the races existed to the extent supposed in the above hypothesis, it is evident that under the present conditions negro blood *can not* permeate the white. Mr. Bruce ("Plantation Negro," p. 243) claims that this intercourse practically does not exist, except in the cities, and that it is on the decline in the cities. Certain it is that miscegenation in the south is meeting with little toleration.

ana, Tennessee and Kentucky is $19,000 less than the yearly income of Harvard University.[12]

A southern state university considers itself fortunate if it receives an annual appropriation of from $50,000 to $75,000; and whereas in the larger universities, like Harvard, the professors teach from five to ten hours per week, it is necessary that they teach from twenty to thirty hours per week in the southern universities. This practically prevents the southern teachers from becoming great scholars in their respective fields, as they are able to do practically nothing in research work, when all of their nervous energy is expended in the class-room. They can, therefore, contribute but little to the future development of the world's knowledge. This dwarfing of mental power is necessarily experienced in every grade of teacher, starting with the university and ending with the lowest primary school or *vice versa.*

What is naturally to be expected from the conditions just given is conclusively corroborated when we note how seldom an article from a southern scholar appears in the leading journals that are devoted to the propagation of the arts and sciences, and when we observe how seldom a southern writer is quoted by a European savant.

It was a favorite saying of the great French statesman Danton that a *state must first have bread and then education,* thus making education the next necessity of life after bread.

It must be admitted by all that the southern white people are in great need of better educational facilities; and every one must also grant that it is *not* right that the south be sapped of its energies to provide wholly for the education of an inferior race, while its own white population is in such need of better education.

The educators (college presidents, etc.) of the south should recognize and make better known to the people the present conditions of the educational world (which conditions should *not* be hidden under a cloak of self-sufficiency); the statesmen of the south should make them known to the nation; and finally, *it is the duty of the nation to rectify these conditions and assume the responsbility of the education of the negro race.*

Remark

That the southern people in all the states believe in the education of the negro is shown by the fact that the negro is being educated. Still, there are many people, men of foresight and ability, who say that "education spoils good laborers." This great minority of thinkers are as a rule either unmindful or ignorant of the fact that such arguments have been in vogue regarding the education of the lower classes for

[12] See "Educational Endowments of the South," by Elizabeth M. Howe, The Popular Science Monthly, October, 1903.

thousands of years. Still, the education of the masses has ever increased and the world thereby has gradually become more enlightened.

But with respect to the education of the colored people the great objection expressed by those who oppose this education is to be found in the "increasing peril resulting from the *higher* education of the negro."

It may be said that along the higher paths of education but few of those who have been civilized for centuries ever tread, and the higher the paths the fewer those who tread them. As would be expected, this is preeminently the case among the negro population.

The Report of the U. S. Commissioner of Education for 1899–1900, Vol. I., pp. lviii and lix of the preface, shows that 2,061 colored persons out of each 1,000,000 were enrolled in secondary and higher education for the year 1890; for the year 1907 it was 2,517 for each 1,000,000, while the general average for the whole United States had increased from 4,362 to 10,743 per 1,000,000. Thus while the attendance at the colored high school or college had increased somewhat faster than the population, it had not kept pace with the general average of the whole country, for it had fallen from 30 per cent. to 24 per cent. of the average quota.[13]

This report also shows that of all the colored pupils only one in one hundred was engaged in secondary and higher work. These figures correspond almost exactly with those given above that were compiled by Dr. Dabney from different data.

As one teacher can not handle successfully more than from forty to fifty pupils, and as all preachers and doctors should have at least some training in a high school, it is seen how entirely without foundation are the above objections regarding the higher education of the negro.

It is further to be noted that the above averages are for the whole colored population of the United States. The percentage of negro children that attend the high schools in cities, especially northern cities, is much larger than it is for the rural districts in the south. In 1900 the number of negroes in Washington, D. C., was 86,702; in Baltimore, 79,258; in Philadelphia, 62,613; in New York, 60,666, etc.

From the Report of the U. S. Commissioner of Education (1905) Vol, 2, p. 1295, it is seen that 3,349 colored students attended high schools in the territory considered in the present paper. As there are approximately seven million colored people living within this area, *there is not one colored person out of every two thousand population that ever enters the high school.*

[13] See Murphy, "The Present South," p. 61.

SHOULD PSYCHOLOGY SUPERVISE TESTIMONY?

By FABIAN FRANKLIN

PROFESSOR MÜNSTERBERG, of Harvard University, who, by his combination of scientific eminence, active interest in public questions, and rare literary skill, occupies a unique position among those who discuss large educational and social problems, recently made a plea,[1] which attracted wide attention, for the introduction of the tests of experimental psychology as a means of judging of the value of evidence given in courts of justice. To show that a deplorably large part of the evidence given in courts and elsewhere is untrustworthy for one reason or another would have been a work of supererogation; nothing is better established in the minds of all who have to deal with the subject. But, while everybody is familiar both with the phenomena of lying and loose statement, and with the fantastic tricks played by our treacherous memories, it is probable that most persons are unaware of the trouble that lurks in malobservation; and it is solely with the errors which arise from this source that Professor Münsterberg deals in the argument to which we have referred. He presents an appalling array of divergences in the outcome of ordinary observation of the same things by one hundred members of his class at Harvard; and he draws from his results the double conclusion that human observation is incomparably more fallible than is generally supposed, and that courts of justice can, and therefore ought to, test the value of the testimony of witnesses by subjecting them to the examination of the expert psychologist. If Professor Münsterberg is right in these conclusions, they are certainly deserving of the earnest attention both of psychologists and of lawyers; but, while his argument drew forth wide-spread comment, it does not seem to have been anywhere discussed with any thoroughness. And it is the purpose of this paper to show that neither the sweeping pessimism as to human reliability which would result from accepting the record given by Professor Münsterberg at its face value, nor the practical plea that he urges for the classifying of witnesses by the methods of experimental psychology, is justified upon careful examination of his argument.

To pass in review each one of the tests detailed by Professor Münsterberg, and attempt to measure the degree in which the whole array falls short of establishing the contentions which it is designed to support, would require the quotation of almost the whole of the article,

[1] *McClure's Magazine*, July, 1907.

tedious, and would demand a greater amount of space than this magazine could be expected to furnish. The nature of the objections to the article can, however, be made clear without so comprehensive and minute an examination.

Let us, in the first place, take a single one of the tests, that relating to the size of the moon:

> My next question did not refer to immediate perception, but to a memory image so vividly at every one's disposal that I assumed a right to substitute it directly for a perception. I asked my men to compare the size of the full moon to that of some object held in the hand at arm's length. I explained the question carefully, and said that they were to describe an object just large enough, when seen at arm's length, to cover the whole full moon.

The answers ranged from a carriage-wheel to a pea; and on this result Professor Münsterberg makes a number of interesting comments. "To the surprise of my readers, perhaps," he says, "it may be added that the only man who was right was the one who compared it to a pea. It is most probable that the results would not have been different if I had asked the question on a moonlight night with the full moon overhead. The substitution of the memory image for the immediate perception can hardly have impaired the correctness of the judgments. If in any court the size of a distant object were to be given by witnesses, and one man declared it as large as a pea and the second as large as a lemon-pie and the third ten feet in diameter, it would hardly be fair to form an objective judgment till the psychologist had found out what kind of a mind was producing that estimate." And elsewhere he refers to the fact that his students do not know "whether the moon is small as a pea or large as a man."

Now, this experiment, damaging as Professor Münsterberg considers it, has, in point of fact, no bearing whatever upon the perceptive powers of his students. If they understood perfectly what his question meant, and shaped their answers accordingly, those answers were the outcome of some kind of conscious mental calculation or experimentation (unless, indeed, we suppose that some of the students, for example the one with the pea, had made the explicit experiment of the obscuration of the moon by an object held at arm's length, and remembered the result). There is absolutely nothing in our direct perception of the moon to give us any idea of the angle it subtends, or of the size of an object which, held at arm's length, would "just cover it." Professor Münsterberg is, indeed, in this dilemma: either he wants to know what the intuitive feeling of a given man is as to the apparent size of the moon when he looks up at it, or he wants to know just what he explicitly declared—what object, held at arm's length, would cover it from the eye (*i. e.*, one eye). If he means the former, the intuitive feeling, each person is the final arbiter of the question—he is either lying or telling the truth; the moon either does or does not seem to and a commentary of even greater length. Such a procedure would be him to be of the size of a plate, a cart-wheel, or what not, and there's an end. His answer can not be challenged on the score of malobservation; one may impeach either his memory or his truthfulness, but not the accuracy of his observation or even of his judgment. In other words, if the man misunderstood the question, and was really answering this other: "How large does the moon instinctively appear to you?" his answer, "as large as a carriage-wheel" or "as large as a one-cent piece," is better than any that either the psychologist or the astronomer can supply for him. If, on the other hand, the student understood the question as it was "carefully explained" by Professor Münsterberg, he absolutely deceived himself if he imagined that his "perception" of the moon's size had anything to do with the answer. We do not, by direct perception, actually estimate the angle subtended by an object, nor do we perform any equivalent operation. For any object within a small distance, we automatically make absolutely complete compensation for the diminishing angle under which it is seen as the distance increases; a plate, a silver dollar or a pea, held at arm's length, *looks* precisely as large as it does when held at the distance of a foot—we have no consciousness whatsoever that the angle it subtends is only one third as great in the former case as in the latter. The moon subtends an angle of half a degree; a large pea at arm's length does the same; a large pin's head, perhaps, does the same a foot away from the eye. But the keenest observer in the world is no more aware of these things by direct perception than is the most ill-constructed member of Professor Münsterberg's class. Our automatic compensation for diminishing angle becomes very imperfect both at great distances and in unusual circumstances—such as looking down upon the floor of the rotunda of the capitol from the gallery at the top; and for celestial objects, like the sun and the moon, it of course falls infinitely short of requirements. We make *some* compensation, though immeasurably less than what is required; and the well-known fact that people differ enormously in their feeling of the apparent size of the moon merely shows that the amount of this compensation (which, in any event, has no simple relation to the actual size and actual distance of the moon) is very different with different persons. But, strangely enough, Professor Münsterberg seems to lose sight of all these facts, and actually to regard the question of the apparent size of the moon as identical with the mathematical question of the angle that it subtends —or, what comes to the same thing, the size of an object which, held at arm's length, will "just cover" it. For while he "carefully explained" the question as meaning the latter thing, his comments relate to the former; and, in particular, in the closing remarks of his article, he speaks of his students not knowing whether "the moon is small as a pea or large as a man." By "is," he of course means "seems";

but this is a radically different question from the one specifically stated at the outset. Thus the master himself clearly slipped from one meaning to the other; and we may be quite certain that some of the answers of his students were intended for one interpretation of the question and some for the other. I feel quite sure that no member of Professor Münsterberg's class really thinks, when he looks up at the full moon, that a solid disk of the size of a carriage-wheel held up at arm's length would just suffice to shut it out from his view. He knows very well that that would shut out a considerable part of the whole sky; and the man who gave "a carriage-wheel" as his answer was almost certainly speaking of how large the moon seemed to him and not of the other question.

This example, from its peculiar nature, has required much space for its discussion; and I hasten to add that, in singling it out, I have put Professor Münsterberg's worst foot foremost. In no other of the instances is there involved, as in this one, a fundamental error. Yet a defect which, in this instance, reached the proportions of downright error is in some measure present in nearly the whole of the article. The defect I have reference to is a failure adequately to discriminate between conscious inference or conjecture, on the one hand, and the immediate dictum of sense-perception, on the other. I am perfectly aware—and it is a commonplace not only of books on logic and psychology, but also of the ordinary text-books of law—that no sharp line can be drawn between these two things. In almost every judgment, however immediately it seems to be given by the impressions made on our senses, an element of inference, conscious or unconscious, enters. Yet there is a vast difference between different cases; and, furthermore, a difference which is distinctly recognized by the wayfaring man. Professor Münsterberg begins his article by citing contradictions of testimony as to whether a road was dry or muddy and as to whether a man had a beard or not; but the staple of his article relates to estimates of the number of spots irregularly scattered on a sheet of cardboard, the rapidity with which a pointer moves around a circular dial, the interval of time between two clicks, and the like. Nowhere does he intimate that there is any vital difference between questions like these and questions of the simpler kind with which he starts out. But when a man is asked how many people he sees in a hall or how fast a train is moving, he knows perfectly well that the validity of his answer is of a wholly different nature from that which attaches to his statement as to whether the road in front of him is wet or dry, or whether a man he is looking at has or has not a beard. In the former cases, he is guessing or consciously estimating, and *knows* he is guessing or consciously estimating; but when he says that the road in front of him is wet or that the man he is looking at has a beard, he is making an assertion in which he places implicit reliance as the direct result of the evidence of his senses. Most of the examples dwelt upon by Professor Münsterberg are simply proofs of the want of skill of his students—and of most persons—in making certain kinds of *numerical estimates*. This is interesting, and even important; but it has no such range of bearing as Professor Münsterberg seems to impute to it. And unfortunately in the only instances in which the verdict called for turned on an immediate sense-perception, the subject-matter chosen was of such a character as greatly to reduce the significance of the result. To ask whether a bit of blue paper or a bit of gray paper is the darker is to ask a technical question; the plain man simply can not put himself into the proper attitude of mind to dissociate the question of color from that of illumination, and the most natural conclusion from the failure of a number of Professor Münsterberg's students to answer the question correctly is that they had not succeeded in training themselves to that special task. The other case of direct perception is open to a similar objection. Professor Münsterberg "asked the class to describe the sound they would hear and to say from what source it came. The sound which I produced was the tone of a large tuning-fork, which I struck with a little hammer below the desk, invisibly to the students. Among the hundred students whose papers I examined for this record were exactly two who recognized it as a tuning-fork tone. All the other judgments took it for a bell, or an organ-pipe, or a muffled gong, or a brazen instrument, or a horn, or a 'cello string, or a violin, and so on. Or they compared it with as different noises as the growl of a lion, a steam whistle, a fog-horn, a fly-wheel, a human song, and what not." What does this show but that to the habitual thoughts of a great majority of the men the tuning-fork is highly unfamiliar? Otherwise nothing but diabolical perversity could have caused 98 out of 100 of the men to declare that some other instrument had produced the sound. When driven to a guess as to what some highly unfamiliar object is whose existence is announced to one of our senses, we do the best we can under the circumstances; but this is something quite different from what we habitually do under ordinary circumstances. I know of a teacher who, whenever his entire class did phenomenally badly in answering a particular examination question, inferred not that the class was stupid, but that the question was an unfair one.

While, then, nothing can be more certain than that great dangers lurk in the possibilities of malobservation, I think I have shown that the case of the average man is by no means as bad as an uncritical acceptance of the specific charges against him so formidably presented by Professor Münsterberg would lead one to believe. One of them falls down completely; most of the others relate to matters that are universally recognized to be matters of estimate or conjecture, and yet are used by Professor Münsterberg as though bearing with full force on the question of the reliability of ordinary simple observation; and even the two remaining ones have peculiarities which greatly restrict their significance. Indeed, a moment's reflection would be sufficient to convince one that things are not as bad as they look through the professional glasses of Professor Münsterberg. If our immediate perception of the things around us, or even our judgment of times, distances, velocities, etc., were as desperately deficient as the whole tenor of Professor Münsterberg's article implies, the world could not be carried on as it is. Business transactions take place every day by the hundred million which turn on the unhesitating recognition of a rarely seen face, and the number of cases of mistaken identity is infinitesimal in comparison; we cross in front of trolley-cars and automobiles and bicycles millions of times just near enough to escape being run over, to once that we actually get run over. To translate that fine judgment of time and distance which brings us safely across Broadway into terms of feet and seconds is a task that most of us perform extremely ill; but this is a particular matter affecting the value of testimony of a special kind, and not touching the general reliability of human observation. This latter is itself undoubtedly highly impeachable; but Professor Münsterberg's tests add little, if anything, to the impeachment.

But there is another side to Professor Münsterberg's article. It is designed not only to show how frequently observation is untrustworthy, but also to advocate a method of classification of witnesses by which the trustworthy ones may be separated from the untrustworthy. "The progress of experimental psychology," he says, "makes it an absurd incongruity that the state should devote its fullest energy to the clearing up of all the physical happenings, but should never ask the psychological expert to determine the value of that factor which becomes most influential—the mind of the witness." That an appeal to psychological experts may in certain special cases be necessary or desirable I do not at all wish to deny; but it seems very clear to me, from the evidence of Professor Münsterberg's own paper, that any attempt to introduce psychological tests as a regular part of the machinery of courts in their dealings with witnesses would be utterly futile. It is conceivable that psychological experts who combined the highest scientific attainments with the most consummate common sense, and the greatest precision of reasoning with the utmost practical caution and shrewdness, could, by subjecting a witness to a sufficiently comprehensive examination, arrive at an authoritative determination of the weight that ought to be attached to his account of the facts which he alleges to have come under his observation; but nothing short of this would suffice. The difficulties in the way are many and great; but first and foremost among them comes the distinction between a laboratory experiment and the involuntary or unregulated experience of real life. Certainly accuracy of observation, whatever other elements it turns on, turns very largely on the question of attention or interest;

and the state of the attention or interest of the observer is wholly different in the ordinary circumstances of life from what it is when the observer is being tested by the psychologist. It is entirely possible that when fifty little black squares irregularly pasted on a large sheet of white cardboard are exposed for five seconds to the gaze of *A* and *B*, *A* will make a much better guess than *B* at their number, owing to his ability to concentrate his attention or to make a swift calculation; and yet that if *A* and *B* were in a hall with fifty people in it, *B* would instinctively have a much better idea of the number of people in it than *A*, owing to a habit of being interested in the scenes of which he is a natural part and in their significance. Again *A*, fixing his attention on the end of a black pointer moving over the edge of a white dial, may be vastly better able than *B* to get that ratio of the consciously observed space to the consciously observed time which is the velocity Professor Münsterberg desired his students to measure in one of his experiments; and yet if *A* and *B* were walking casually along the street, *B* might be an incomparably more reliable witness on the question whether an automobile was or was not exceeding the legal speed limit. And this matter of the different distribution of interest in different circumstances is only one of a vast number of elements which go to making the psychologist's test highly precarious. You must catch a man "in his habit as he lives," you must follow him into all sorts of situations under all sorts of circumstances, internal and external, before you can decide what value to attach to his statement as to the facts that come into his ordinary experience of daily life. The man who may be too dull-witted to understand the psychologist's question, too lethargic to make a decent observation of what is put before him by his examiner, or too "rattled" to state correctly the result of that observation, may be a man who, as he goes about his work or chats with his fellows, misses nothing of the ordinary human occurrences that take place around him. And, on the other hand, the man of quick intelligence and keen activity who, upon demand, can bring all his faculties to bear upon a subject on which he is challenged to make a creditable report may, not only *in spite* of having this temperament, but actually *because* of it, be the very man who habitually takes extremely imperfect notice of the visible and audible things that are going on around him all the time and that have for him no significance.

Difficulties like these—I do not say insuperable difficulties, but certainly difficulties that offer enormous resistance to the investigator—are inherent in the subject. But over and above these inherent difficulties are those which attach not so much to the investigation as to the investigator. As a practical proposition, Professor Münsterberg's project must contemplate the employment of the psychological expert as an expert, strictly speaking. His report on the capacity of a witness must be taken by court and jury on his authority; it could not be expected of the court, still less of the jury, that it should examine into the soundness of the methods which he had employed. Yet it must be plain from what has been pointed out above that, even assuming—which is a great deal—the possibility of expending the necessary amount of time and pains upon the inquiry, none but the most highly qualified expert could be safely entrusted with it. Professor Münsterberg is a man not only of the highest professional training, but of extraordinary native powers of mind; yet he not only makes a fundamental error in one instance, but in a number of others overlooks elements essential to the true bearing of the facts upon the question in hand. In addition to the points already noted, one other may be mentioned which throws perhaps an even stronger light on the pitfalls that lie on all sides. It is a curious circumstance that in none of the questions put by Professor Münsterberg to his class does he give any room (or at least any encouragement) to the simple answer, "I don't know." How many of the queer guesses he got in response to the question as to what caused the sound he made by striking the hidden tuning-fork would have been choked off by the simple and straightforward plan of telling the students to answer only in case they felt a reasonable assurance, there is no means of telling. And yet in court a truthful witness would do that very thing. If he had heard a sound the character of which he could not identify, he would so state to the court, and not say it was a bell or a church organ or a human song or what not. A man who, upon being asked to make the best guess he can, makes a very bad guess is not necessarily an unreliable witness; he may be the very man who on the witness stand would refuse to testify to things that he doesn't feel sure of, and who, when he does make a statement, may be implicitly believed. And the same remark applies, in some measure, to nearly all the tests in Professor Münsterberg's questionary. If Professor Münsterberg has laid himself open to criticism in so many points, how much less would it be possible to entrust to an every-day psychologist the decision of so delicate a question as that of the degree of reliability of each of the witnesses in a given case?

There is one very striking test, of a different character from any of the others, to which I have made no reference, and which might be pointed to as concrete proof of the correctness of the method in spite of any criticism that may be brought against it in the abstract. This is an experiment in which Professor Münsterberg, having asked his class to describe everything that he was going to do from one signal to another, did certain conspicuous things with his right hand, upon which he ostentatiously fixed his own attention, while at the same time he did a number of other things with his left hand. The result was that 18 out of 100 students were utterly unaware that he was doing anything at all with his left hand. This of itself would not be surprising, it being a phenomenon familiar in all sorts of sleight-of-hand performances; but the striking fact was developed that of these eighteen non-observers fourteen were included among the twenty men (or thereabout)[2] who had judged a dark blue to be lighter than a certain lighter gray. "That coincidence," says Professor Münsterberg, "was of course not chance. In the case of the darkness experiment the mere idea of grayness gave to their suggestible minds the belief that the colorless gray must be darker than any color. They evidently did not judge at all from the optical impression, but entirely from their conception of gray as darkness. The coincidence, therefore, proved clearly how very quickly a little experiment such as this with a piece of blue and gray paper, which can be performed in a few seconds, can pick out for us those minds which are utterly unfit to report whether an action has been performed in their presence or not. Whatever they expect to see they do see; and if the attention is turned in one direction, they are blind and deaf and idiotic in the other." That the coincidence is not a matter of chance may be admitted as practically certain; and yet there is ample room for disputing the inference which Professor Münsterberg draws from it. He finds in it a triumphant proof of the adequacy of an extremely simple and special little test for a sweeping conclusion as to the general powers of observation of the men subjected to it. But surely there is another possible explanation. There is one thing that both the color test and the sleight-of-hand test have in common; the danger of a wrong answer in either case may lie chiefly in a failure on the part of the student to grasp firmly and clearly the exact and full import of the question. The man that is alert and keen-witted and intent in his attitude toward the test will both know exactly what is meant by the question of the relative brightness of the two colored papers and be on his guard as to the possibility of a trick (for that is what it is) in the attempt to concentrate his attention upon the spectacular doings of the right hand. The man less keyed up to the requirements of the tests will be in danger both of failing to make the requisite discrimination in the question of brightness and of falling into the trap laid for him in the sleight-of-hand performance. Professor Münsterberg may have (but he certainly does not mention it) confirmatory evidence of the conclusion he draws from the coincidence; but on the face of it that coincidence may quite as plausibly be accounted for in the manner I have indicated as it is by the supposition that an inability to determine which of two differently colored paper squares is the darker carries with it a high probability that the observer is "utterly unfit to report whether an action has been performed in his presence or not." The common observation of every-day life is of a radically different character from what is

[2] "About one fifth of the men" is Professor Münsterberg's statement.

involved in either of these two associated tests; and the man who distinguishes himself in both may, in ordinary life, with his senses and his intellect in their normal state, be a far worse observer and a far worse reporter of the things going on around him than the man who is either too indifferent or too slow-witted to bring his mental and physical faculties to bear adequately upon the artificial test.

It is far from being the purpose of this paper to cast discredit on the methods of experimental psychology. On the contrary, the writer feels that the advance made by that science has been among the most interesting and important of the scientific developments of the past three decades. In Professor Münsterberg's succeeding paper, "The Third Degree," for example, are to be found a number of illustrations of the remarkable results that have been obtained by the methods of experimental psychology. The account of them given by the distinguished professor with that skill and attractiveness of which he is a rare master, while as interesting as a romance, is full of convincing force. The questions there discussed have at once intense theoretical interest and great practical importance; but there is this difference between them and the questions at issue in the paper I have been criticizing: In worming out of a suspect, or a hysterical patient, the secret he is endeavoring to guard, the thing under examination by the expert is highly definite. It is something in the actual contents of the subject's mind or in his emotional susceptibility on certain definite matters. The study of his reaction-times, association-times, etc., has been shown to furnish astonishingly definite information on these specific things. The point made in the present paper is simply that no such case has been made out in the much broader, looser, more varied and more intangible region covered by the question of the trustworthiness of every-day human observation; that the indictment brought against such observation, not so much by the exact letter as by the whole tenor of Professor Münsterberg's article, is not sustained by his instances; and finally that, so far as regards the discrimination of trustworthy from untrustworthy witnesses (truthfulness aside) as to the affairs of ordinary life, the investigation by expert psychologists, in order to be entitled to authority, would have to be vastly more comprehensive and vastly more able than there is any practical possibility of commanding. That there are special classes of cases in which the expert's investigation of a witness would be of value is certain, but the scope of his usefulness must be regarded as severely limited. So far as the ordinary run of things is concerned, the present homely procedure, imperfect as it is, is to be preferred to a system in which, over and above the question of the trustworthiness of witnesses, there would be injected into every case of importance the further and at least equally puzzling question of the trustworthiness of the tests employed by the psychological expert.

THE PROGRESS OF SCIENCE

THE CARNEGIE FOUNDATION FOR THE ADVANCEMENT OF TEACHING AND THE STATE UNIVERSITIES

Science and higher education in this country have been placed under further obligation to Mr. Andrew Carnegie for his generous intentions in adding $7,000,000 to the endowments of the two institutions that bear his name. The Carnegie Institution of Washington has been given $2,000,000 without special conditions, and the Carnegie Foundation for the Advancement of Teaching has been given $5,000,000 in order that its system of retiring allowances may be extended to state universities.

If the cost of steel had not been excessive through the tariff and the cost of kerosene had not been excessive through monopoly, every state in the union could have afforded to endow institutions for scientific research equaling the Carnegie Institution of Washington, and universities equaling the University of Chicago. But they would not have done so; nor would the gains of the people have been saved and combined to carry forward the construction of railways and other enterprises which the capitalistic system has accomplished. It is one of the anomalies of our complicated civilization that the tariff and the trusts, apparently for the benefit of capitalism, are long steps in the direction of state socialism, whereas the universities supported by the states are the nurseries of democratic individualism.

These remarks are suggested by the paternalistic and centralistic character of the pension system now extended to the state universities. Whether this extension is a benefit or an injury to these institutions is a question not at all easy to answer. It was urged by a committee of the presidents forming the National Association of State Universities, whose chief argument was that it is unlikely that the states will provide pensions for professors, as this might raise the question of pensions for all public officers, and that the state universities would thus be at a great disadvantage as compared with private institutions. President Pritchett of the foundation, in his report on the subject printed last year, argued that the desirability of the pension system and its adoption by the private institution would force the states to provide it for their universities.

But the desirability of a uniform and universal pension scheme for professors is at least open to question. If one university pays a salary of $3,000, and another pays $2,500 and provides an annuity the annual cost of which is $500, the charge to the institution and to society is the same. In which is the position of the professor preferable? Those who insure themselves for the benefit of wife and children are better citizens than those who stint their families in order to buy annuities for their own old age; but it seems that college professors are to be compelled to join the latter class. They must sacrifice a certain amount of freedom in accepting annuities in place of salary and are put into a caste that they can not leave without serious money loss.

On the other hand, it may be argued that the scholar should be relieved from all financial responsibility, in order that he may be free to do his work. It is also claimed that it is an advantage for an institution to be able to replace its older professors with younger men. The introduction of the system is of financial advantage to men already in the service of institutions that did not have pensions, as they get an annuity for which they have not paid. And, of course, Mr. Carnegie's liberal gift provides additional income to institutions for higher education. Hence it is favored by university presidents and from this point of view is not unwelcome to professors. But the present writer regards the increase in the course of ten years of the annual appropriations for ten of the western universities from $1,689,000 to $4,577,000—equivalent to an increase in endowment of some $75,000,000—as immeasurably more significant than the extension of Mr. Carnegie's pension scheme to these universities.

THE VEGETATION OF THE SALTON SEA

We have published several articles on the scientific and engineering problems arising from the overflow of the

THE DELTA OF THE COLORADO RIVER
INCLUDING THE SALTON AND PATTIE BASINS
Compiled and drawn by Godfrey Sykes
1907

ALKALINE SLOPE ON THE SHORE OF SALTON SEA.

Colorado River into the Salton Basin. It will be remembered that in the autumn of 1904 an irrigation ditch was eroded into a stream that carried an enormous amount of water from the river into the sink—at its lowest level 280 feet below that of the sea—and formed a lake some five hundred square miles in extent, which threatened to extend and submerge a flourishing district. After repeated failures and the expenditure of several million dollars, the overflow was checked early in 1907.

The submergence of this area and its drying up have caused and will cause changes in the vegetation which may throw light on the distribution of plants, and the Department of Botanical Research of the Carnegie Institution, under the direction of Dr. D. T. MacDougal, with its Desert Laboratory at Tucson, Arizona, was in a position to take up this problem. It has been extended to the Pattie Basin, into which flood water escapes nearly every year. The general plan of the work is described in the last Year Book of the institution, from which the accom-

DESERT WASH OCCUPIED BY AN ARM OF THE SALTON SEA.

panying map and illustrations are taken.

Early last year an expedition was organized and embarked in a sailboat, designed for the circumnavigation of the Salton Sea and an examination of its contacts with the adjacent desert vegetation. Six stations were selected from which under varying conditions the succession of vegetation will be studied as the water recedes. The maximum depth of the water is 84 feet, and it is expected that most of it will evaporate in about ten years. Its width is from five to twenty-five miles, and each year new stretches of beach will become available for occupation by plants. The level of the lake fell about one foot by June 1, and two or three feet six months later. At that time the strip of saline shore left bare had not been occupied by plants.

The Desert Laboratory has under way various other studies in acclimatization and the influence of physical features on vegetation. Thus four stations have been chosen at elevations, respectively, of 2,200, 2,700, 6,100 and 8,000 feet, and transplantations cause marked structural changes in the plants. Attention is given to the determination of whether these changes are transmitted and persist in localities other than the one in which they originated.

JOHN SAMUEL BUDGETT

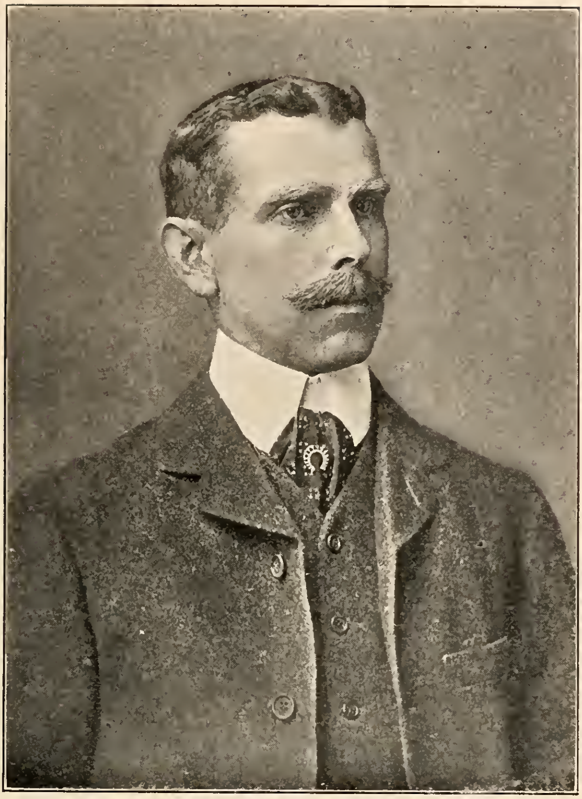
It is becoming that honor should be paid to those who sacrifice their lives for science. One of the strongest props of militarism is the instinctive respect commanded by the soldier who is ready to die for his country. It should be widely known that in laboratories and in the field men of science are quietly at work with dangerous organisms, with poisons and explosives, exposed to disease, accepting risks for the advancement of science and the welfare of man greater than those to which the soldier is liable.

A fitting tribute to one of this company of scientific martyrs has been paid in the publication of a volume in memory of John Samuel Budgett, who died from fever contracted in several visits to the jungles of South America and Africa. He had gone in search of zoological material and especially to study the development of *Polypterus*, which is one of the two surviving forms of the great group of fishes that flourished in the Paleozoic and Mesozoic periods.

The memorial volume, which is beautifully printed by the Cambridge University Press, contains a biographical sketch of Budgett by Professor A. E. Shipley, a collection of his zoological papers and several papers by Mr. Richard Assheton and others, consisting of the completion of the work begun by Budgett on the material that he had collected.

Budgett was born at Bristol in 1872. Like nearly all those who have done good work in natural history, he showed early his interests and aptitudes. As is so often the case, his father was keenly interested and naturalists visited his house; he was irregular in his school attendance and did not do very well at examinations. Before he completed his course at Cambridge, he went with Mr. Graham Kerr to the Gran Chaco of Paraguay in search of *Lepidosiren*. The expedition was brilliantly successful and brought back a large supply of specimens of this practically unknown lungfish, including eggs and larvæ in all stages of development. Budgett's first paper was an account of the batrachians of the Paraguayan Chaco, published in 1898.

After obtaining his degree, he took up with dauntless courage the search in Africa for *Polypterus*, about whose habits and development nothing was known, but whose primitive condition might be expected to throw light on the origin and relationship of fishes. In search of these fishes Budgett visited the Gambia, the Victoria Nile and the Niger, undismayed by innumerable difficulties including malaria



JOHN SAMUEL BUDGETT.

and blackwater fever. He obtained a vast amount of important scientific information in regard to *Polypterus* and in other directions, and in his last expedition accomplished the artificial fertilizing of the eggs and the study of their development. But he sacrificed his life to attain this end, and died before completing his work at the age of thirty-one.

SCIENTIFIC ITEMS

WE regret to record the deaths of Dr. William Ashbrook Kellerman, professor of botany at the Ohio State University, from tropical fever while engaged in the study of the flora of Guatemala; of Dr. Edouard Zeller, the eminent historian of philosophy, at the age of ninety-four years; of Dr. William Edward Wilson, F.R.S., who had carried on important research in his astronomical observatory and astrophysical laboratory on his estate in Westmeath, Ireland; of Dr. H. C. Sorby, F.R.S., known for his researches on the microscopical structure of rocks and metals; of Sir John Eliot, F.R.S., eminent for his services to meteorology; of Dr. A. Howitt, author of important anthropological works on the natives of Australia; of Sir Denzil Ibbetson, known for his contributions to the ethnology of India; of Sir Alfred Cooper, a distinguished London surgeon, and of Professor Laurent, professor of mathematical analysis at Paris.

MAJOR GENERAL A. W. GREELY, eminent for his arctic explorations and his services to meteorology, having reached the age of sixty-four years on

March 27, was transferred to the retired list in accordance with law.—The Turin Academy of Science has conferred the Bressa prize of about $2,000 on Dr. Ernest Rutherford, professor of physics at Victoria University, Manchester.—Dr. W. M. Davis, Sturgis-Hooper professor of geology, has been selected by the German government as Harvard visiting professor at the University of Berlin for the academic year 1908–9.—President Eliot, of Harvard University, delivered in April six lectures at Northwestern University on the Norman W. Harris Foundation. His general subject was "University Administration."

Provision will be made by the Canadian government in the estimates for the coming financial year for a grant of $25,000 by the Dominion parliament towards the expenses of the visit of the British Association to Winnipeg. The city of Winnipeg proposes to make a grant of $5,000. The week of the meeting will probably be from August 25 to September 1, 1909. Dr. J. J. Thomson, Cavendish professor of experimental physics at Cambridge, will preside.

In the bill making appropriations for the Department of Agriculture for the fiscal year ending June 30, 1909, and just introduced into the House, the total sum appropriated is $11,431,346. Of this amount the following sums are appropriated to what may be termed the scientific bureaus and offices of the department: Forest Service, $3,796,200; Weather Bureau, $1,662,260; Bureau of Plant Industry, $1,331,076; Bureau of Animal Industry, $1,330,860; Bureau of Chemistry, $791,720; Bureau of Entomology, $434,960; Office of Experiment Stations, $230,620; Bureau of Statistics, $221,440; Bureau of Soils, $204,700; Office of Public Roads, $87,390; Bureau of Biological Survey, $62,000, making a total of $10,254,226.

The Kentucky legislature, recently adjourned, changed the name of the College of Agriculture and the Mechanic Arts to the State University and appropriated to it $200,000 in addition to what it has already been receiving; $30,000 of this amount is to be annual. At the same time it appropriated $150,000 each to the two new State Normal Schools.—Plans for two new buildings have been accepted by the board of trustees of the University of Illinois. One is a physics laboratory, to cost $250,000, the other an extension of the natural history building, to cost $150,000.

// THE POPULAR SCIENCE MONTHLY

JUNE, 1908

THE MOVEMENT TOWARDS "PHYSIOLOGICAL" PSYCHOLOGY. I

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Like many words of broad sweep and intensive significance, the term "soul" has descended to us laden with centuries of righteousness—and iniquity. Even yet some folk roll it as a sweet morsel under the tongue; while others, seeing it is neither hot nor cold, would spew it from their mouths forthwith. Consequently, whereas the very title "psychology" means a study of the soul, to-day one seldom hears the too suggestive name inside a psychological laboratory, for there we have no inclination to the *double entendre*. And the impression has gone abroad that this altered attitude dates from very recent times. Accordingly, it is necessary to point out, first, that traces of a psychology rooted in physiology, that is, of psychology as a natural science, did not begin yesterday, indeed, they may be said to antedate physiology itself. Thus, while it may be needless to consider Pythagoras's alleged discovery, that the tones in an octave are results of relations between physiological movements capable of numerical measurement, or Aristotle's extraordinary prevision, of the study of ψυχή as a matter for the physiologist,[1] we can not omit reference to post-Renascence thought.

As happens so often, especially when a recent movement attains its heyday, the "heroes before Agamemnon" are apt to be robbed of all credit. Flushed by the success of experimental methods, some have tended to forget that the forerunners did but what they could. To accuse them of interrogating themselves "without information, experience, apparatus, or means of procedure,"[2] to blame them for their inexactness and mysticism, or for their subservience to preconceived beliefs, to individual fancies and predilections, is to evince lack of

[1] *De Anima*, I., i., 403^a, 25.

[2] "German Psychology of To-day," Th. Ribot, p. 5 (Eng. trans.).

historical sense. They groped in the dim, grey dawn of science, without our advantages, but they set the problems which we attack hopefully in the bright glow of early morning. If, then, we remember this, we shall be less surprised to learn that, leaving many lesser lights aside, at least two dozen men, between Locke (1690) and Lewes (1860), play their preparatory parts to Fechner, Wundt and the devoted contemporary group of psychological coworkers. To make this clearer, let me adduce some names, adding the approximate dates of most significant activity. Locke, 1690; Berkeley, 1709; Lavatar, 1772; Kant, 1781; Herder, 1785; Galvani, 1786; Cabanis, 1801; Volta, 1801; Gall, 1805; Spurzheim, 1813; Young, 1807; Sir Charles Bell, 1811; George Combe, 1820; Herbart, 1825; Fourier, 1825; Js. Müller, 1835; Beneke, 1835; E. H. Weber, 1846; du Bois Reymond, 1848; Lotze, 1852; Helmholtz, 1856; Bain, 1857; Lewes, 1860; Fechner, 1860; Wundt (1874), the inheritor of all this renown, who, in a manner parallels for psychology Darwin's position in natural history.

Our next task is to unravel the tangled skein of investigation and tentative hypotheses, of discovery and unsolved problems, for which these names stand. This is no easy thing, because some of the threads can not be disentangled. But we may contrive to render the situation less puzzling, and so see how we came to stand where we have been for the past twenty years.

Premising that they cross, recross, and even coincide occasionally, three lines of development may be traced. These are: *First,* the philosophical, in the accepted sense of this term, which originates, of course, in a view of human experience as a whole, or, restricting the compass somewhat, emphasizes the gross organization of consciousness; *second,* the physical, which lays stress on the relation of certain events in consciousness to objects presented under the primary conditions of space and time; *third,* the physiological, which founds on the interconnection between conscious processes and the structures of the body, particularly the cerebro-spinal system. As every one knows, the first appeared earliest, while the second and third, being dependent upon the advance of positive science, had to await what we may call the Newtonian and genetic epochs, the one initiated by Copernicus, the other by Herder and Schelling. Till the age of Kant, philosophy and physics are dominated by British thought, all things considered; from Kant till the first quarter of the nineteenth century French thought acquired increased importance; thereafter, the primacy passed to Germany, where it still remains, the influence of Darwinian ideas aside (and so I shall omit reference to the later British school). For, physiology and physiological psychology, along with the problems issuing from the new outlook, are German products in the main. The synthesis of information constituting the modern science of consciousness was "made in Germany."

I

The point of departure, then, lies in the philosophical line. Little as he could foresee the future influence of his theory, Locke raised, in a manner, the entire question of the relation between consciousness and the physiological organism by his famous distinction between the primary and secondary qualities of body.[3] Qualities like color, odor, hardness and sound, he called secondary, because they can not become effective components of consciousness unless the appropriate organs cooperate. Neither color nor sound resides in nature, but motions of such and such amplitude. For us, therefore, color and sound happen to be interpretations by eye and ear of something incommensurable with the perceptions *in* consciousness. On the contrary, qualities such as resistance and extension belong to objects in their own right, and persist independent of any cooperation by our sense organs. Locke did not grasp the philosophical problems involved here, much less the extreme complexity of the physiological processes he assumed. However, he does advert to one of the difficulties embedded in his view—the "mystery," as it remains even yet, of space perception:

> I shall here insert a problem of that very ingenious and studious promoter of real knowledge, the learned and worthy Mr. Molineux, which he was pleased to send me in a letter some months since; and it is this:—"Suppose a man *born* blind, and now adult, and taught by his *touch* to distinguish between a cube and a sphere of the same metal, and nighly of the same bigness, so as to tell, when he felt one and the other, which is the cube, which the sphere. Suppose then the cube and the sphere placed on a table, and the blind man be made to see: *quaere,* whether *by his sight, before he touched them,* he could now distinguish and tell which is the globe, which the cube?" To which the acute and judicious proposer answers, "Not. For, though he has obtained the experience of how a globe, how a cube affects his touch, yet he has not yet obtained the experience that what affects his touch so or so, must affect his sight so or so; or that a protuberant angle in the cube, that pressed his hand unequally, shall appear to his eye as it does in the cube."—I agree with this thinking gentleman, whom I am proud to call my friend, in his answer to this problem; and am of opinion that the blind man, at first sight, would not be able with certainty to say which was the globe, which the cube, whilst he only saw them; though he could unerringly name them by his touch, and certainly distinguish them by the difference of their figures felt. This I have set down, and leave with my reader, as an occasion for him to consider how much he may be beholden to experience, improvement and acquired notions, where he thinks he had not the least use of, or help from them.[4]

As the last sentence indicates, this reference remains incidental rather than determining for Locke.

It was left for his successor and critic Berkeley to give special form to the problem for its own sake, in his "Essay towards a New Theory of Vision" (1709). With remarkable prescience, he writes:

> Rightly to conceive the business in hand, we must carefully distinguish

[3] "Essay concerning Human Understanding," Bk. II.; Chap. VIII.

[4] "Essay concerning Human Understanding," Bk. II., Chap. IX., Sect. 8.

between the ideas of sight and touch, between the visible and tangible eye; for certainly on the tangible eye nothing either is or seems to be painted. Again, the visible eye, as well as all other visible objects, hath been shown to exist only in the mind; which, perceiving its own ideas, and comparing them together, does call some pictures in respect to others. What hath been said, being rightly comprehended and laid together, does, I think, afford a full and genuine explanation of the erect appearance of objects—which phenomenon, I must confess, I do not see how it can be explained by any theories of vision hitherto made public. In treating of these things, the use of language is apt to occasion some obscurity and confusion, and create in us wrong ideas. For, language, being accommodated to the common notions and prejudices of men, it is scarce possible to deliver the naked and precise truth, without great circumlocution, impropriety, and (to an unwary reader) seeming contradictions.[5]

That is to say, Berkeley insists upon the necessity for another and more concrete analysis than that afforded by the resources of descriptive language.

Later, in "The Principles of Human Knowledge," Part I., he seems to indicate that this profounder analysis must take a physiological direction:

The philosophic consideration of motion doth not imply the being of an *absolute Space,* distinct from that which is perceived by sense, and related to bodies. . . . When I excite a motion in some part of my body, if it be free or without resistance, I say there is *Space.* But if I find a resistance, then I say there is *Body:* and in proportion as the resistance to motion is lesser or greater, I say the space is more or less *pure.* . . . When, therefore, supposing all the world to be annihilated besides my own body, I say there still remains *pure Space;* thereby nothing else is meant but only that I conceive it possible for the limbs of my body to be moved on all sides without the least resistance: but if that too were annihilated then there could be no motion, and consequently no Space.[6]

Knowing little of physiology, Berkeley leaves the problem, stated so far, indeed, but only stated. It is this: How can we derive space, a general condition of external objects, from states of the body which, in their very nature, differ utterly from this, their product? Twenty-two years later, he returns to the question, and appears to raise it in fresh form. In the Fourth Dialogue of "Alciphron, the Minute Philosopher," he says:

(Euphranor speaks:) "We perceive distance, not immediately, but by mediation of a sign, which hath no likeness to it, or necessary connection with it, but only suggests it from repeated experience, as words do things." (Alciphron replies:) "Hold, Euphranor: now I think of it, the writers in optics tell us of an angle made by the two optic axes, where they meet in the visible point or object; which angle, the obtuser it is the nearer it shows the object to be, and by how much the acuter, by so much the farther off; and this from a necessary demonstrable connection."[7]

It is needless to add that Berkeley, although he makes physiological reference and research inevitable, lived long before such a study of "local signs" as that undertaken by Lotze was practicable.

[5] Sects. 119–20. [6] Sect. 116. [7] Sect. 8.

Thus, the "mystery" is simply held over, to be attacked by Kant, in whose person eighteenth century thought was to give place to a very contrasted movement. For him, space and time, the general forms of human perception of all events in consciousness, are factors not derived from materials supplied by sensation. They belong to the unifying power of perception in its relation to objects which, again, demands the presence of elements presented by sensation. Accordingly, he is quite clear that, for example, geometrical truth must be classed as *a priori;* that is, it can not be distilled, as it were, from those sense materials acquired in the course of experience. Thus Kant forces us to class him as a "nativist." So it does not surprise us to observe that he fails to envisage difficulties which were to become capital for physiological psychology at a later time. For instance: How, as a matter of fact, do we construct our completed perception of space? Granted that it be the product of psychical processes, what are they? Granted that it become effective only in the presence of objects, which presuppose sensuous matter, What does this physiological reference gift to our perception? Or, once more, by what subtle alchemy can we explain the obvious fact that we distribute our sensations in space, as it were? How, that is, can we account for localization? Here we quit the philosophical line for a while, observing that its unanswered questions will reappear in an altered perspective.

II

In the realm of physics, prior to the systematic inquiries of the nineteenth century, several more or less sporadic references to the connection between physical and psychical phenomena occur. Such, for example, were the discussions, by Euler and Daniel Bernouilli, of "the law governing the motions of strings";[8] Bernouilli's theory of the *mensura sortis,*[9] with Laplace's addition of the *fortune physique* and the *fortune morale.* These forecast the laws of psycho-physical relationship formulated by E. H. Weber and Fechner. Similarly, the discoveries of Galvani and Volta led to speculations on a supposed parallelism between the known phenomena of electricity and the so-called "discharges" of innervation which, in a way, plumbed the depths of quasi-charlatanism in the developments from Mesmer, and touched the heights of scientific advance in du Bois Reymond's classical work "Untersuchungen über thierische Electricität" (1848), where the mystical and the physical views passed over into physiology for systematic clarification.

Again, Fourier's Law, that "any given regular periodic form of vibration can always be produced by the addition of simple vibrations, having vibrational numbers which are once, twice, thrice, four times,

[8] "The Sensations of Tone," Helmholtz, p. 23 (Eng. trans.).

[9] "German Psychology of To-day," Ribot, p. 226 (Eng. trans.).

etc., as great as the vibrational number of the given motion";[10] Ohm's analysis of the "periodic motions perceived by the human ear,"[11] and Wheatstone's stereoscope united to demonstrate that the psychical and the physical stand in close connection.

Finally, Young's color-theory, with its three primary colors—red, green and violet—paved the way for a passage from physical to physiological considerations; for it led to the hypothesis of "specific energies" in the nerve-fibers.

Ere we pass to the epoch-making transformations of last century, two movements, discredited in many ways it is true, yet of importance as preparatory, demand recognition. It may surprise us to find that they are phrenology and physiognomy. Gall and Spurzheim, both physicians, substituted for the descriptive and introspective faculty-psychology an anatomical scheme parallel essentially in result. They concluded that the faculties can be localized in definite portions of the brain, and that these, in turn, can be traced by reference to the surface formation of the skull. Phrenology created wide-spread interest early in the nineteenth century—witness George Combe (1828) in Edinburgh, who, it may be interesting to relate, received a call to the chair of philosophy in the University of Michigan, or Caldwell and Godman in this country. Through a long series of fluctuating fortunes their suggestions became effective finally as elements in a scientific physiological psychology when Broca (1861) located the brain-center of speech; and, ever since, thanks to the labors of Hughlings Jackson, Ferrier, Golz, Hitzig and many others, this has provided an important sphere of study to physiological psychology.

In similar fashion, the observations, opinions and speculations of Lavatar, in his "Physiognomische Fragmente" (1772), produced a *furore;* elicited Sir Charles Bell's famous "Essay on the Anatomy of Expression" (1806), with its theory of the relation between intellectual power and the facial angle; and, at last, attained complete scientific consecration in Darwin's masterly book, "Expressions of the Emotions in Man and Animals" (1872).[12] Thus positive error and misleading half-truth sometimes serve to state problems which, otherwise, might have failed to gain hearing. One may conclude fairly, then, that questions about the relation of body to mind were in the air throughout the entire course of the eighteenth century and, at its close, had begun to become clamant.

III

At this juncture philosophical activity assumed unprecedented proportions and left a solid deposit destined to a constructive influence

[10] Helmholtz, *loc. cit.*, p. 52.

[11] Cf. *ibid.*, pp. 23, 51, 89, 102–3.

[12] Cf. "Physiol. Psych.," Wundt, Vol. II., pp. 598 f. (4th ed.).

which, I fear, too few scientific men realize to-day. The years 1780–1840 witnessed an efflorescence of speculative thought unparalleled in western history save once—in that wonderful century (422–322 B. C.) when Socrates, Plato and Aristotle secured for the Greeks a far more permanent and formative hold over mankind than was ever achieved by Aristotle's amazing pupil, Alexander the Great. As at Athens, so in the modern period, transitive intellectual personages are legion. Here it must suffice to mention Herder, Fichte, Schelling, Hegel, Herbart and Beneke. Fichte's previsions of a social science, Schelling's wide-spread sway over nascent physiology and medicine, and Hegel's splendid mission, as founder of contemporary critico-historical and comparative studies that have altered the face of human nature, must be suppressed now. But, for psychology, Herder, Herbart and Beneke present matter of high import.

Herder possessed that rarest of endowments, a seminal mind. His thought scattered seeds everywhere, which have come to fruitage since in philology, comparative religion, anthropology and psychology, to name no others. Genetic conceptions inspired him, and his command of enormous reading enabled him to illustrate them concretely, if sporadically. Under the influence of Albrecht von Haller, the eminent Göttingen naturalist, who founded experimental and brain physiology,[13] he foresaw the necessity of physiological research for psychology. "According to my thinking," he wrote, as early as 1778, "there is no psychology possible which is not at every step definite physiology. Haller's physiological work once raised to psychology, and, like Pygmalion's statue, enlivened with mind, we shall be able to say something of thought and sensation."[14] No less remarkable is the following, in its prophetic insight; "Among millions of creatures whatever could preserve itself abides, and still after the lapse of thousands of years remains in the great harmonious order. Wild animals and tame, carnivorous and graminivorous insects, birds, fishes and man are adapted to each other."[15]

But, admitting Herder's vision to the full, his main title to a distinct place in the historical line of psychologists supplies the reason why, strange as it may seem, we must dismiss him briefly in the present context. The most recondite and, at the same time, most potent quality of self-consciousness roots in its eerie power of objectification. Students brood upon this increasingly, sciences like historical criticism, sociology and æsthetics offering testimony. Men bandy words about the "social mind," about "mob psychology," about a "national or epochal *ethos*," and so forth. Customs and institutions, myth and religion yield paleontological records, not of individual men, but rather of

[13] Cf. "The History of Physiology," Foster, pp. 291 ff.

[14] Cf. "Vom Erkennen und Empfinden der menschlichen Seele," Werke, IX.

[15] Quoted by Sully in the Encyc. Brit. (9th ed.), Vol. XI., *s. v.* Herder.

humanity, a kind of compost of individuals. But the implications hinted here receive their most striking manifestation in language. Now Herder, to give him his due, must be saluted as the herald of *Völkerpsychologie* and of *Sprachwissenschaft*. So he stands aside from the line under examination. For, even if it be recalled that phonology can be classed as a physiological science, the matter terminates there. Great as have been the contributions of W. von Humboldt, Bopp, Grimm, Max Müller and their coworkers, and much as has been accomplished by Waitz, Lazarus, Steinthal, McLennan, Spencer, Lubbock, Tylor, Frazer and Westermarck, all sit more or less loose to physiological psychology, which continues an investigation of individual far more than of group processes. So, attractive and suggestive as Herder is, perforce we rest content now with the bare reference to what I have had the temerity to call his seminal mind.

When we arrive at Herbart and Beneke the case presents a different aspect. For they stand forth among the last great psychologists who deal with mind as mind, to the exclusion of modern experimental methods applicable chiefly to the body. After a manner their services pale in the glow of the contemporary atmosphere; their work has been bemused by pedagogists, misprized overmuch by psychologists, even if, as Wundt says,[16] he owes most to Kant and Herbart, and even remembering the work of Herbartians like Drobisch, Volkmann, Exner, Strümpell, Cornelius and R. Zimmermann.[17]

Note, at the outset, that Herbart (1776–1841) and Beneke (1798–1854) revolt strongly against the dominant Hegelian school, and that both attempt a *concrete* study of consciousness. On one point they differ decisively. Herbart's psychology, as the title of his chief work runs—"Psychology as a Science, founded, for the first time, upon Experience, Metaphysics and Mathematics," possesses a triple basis. Beneke excludes the second and third, emphasizing experience as the sole legitimate foundation. In this respect he takes the pioneer place among those who raised the later cry, "Back to Kant!"

Thanks to the limits of this paper, Herbart's metaphysical doctrine must disappear with a word. He held that the soul, in its own proper nature, forms an original, changeless and simple entity. Psychological processes originate in its resistance to intrusion from the outside, therefore, the complexities of consciousness, just because they are *complex,* fall within the reach of analysis. As results of mechanical interaction they lie open to mathematical methods. Such procedure, of course, leads straight to experience, and, on the whole, it may be affirmed that, as his psychology prospers, the direct influence of his metaphysic wanes. In this way a long step towards psychology viewed

[16] "Physiol. Psychologie," preface to the first edition, 1874.

[17] Cf. *Mind*, Vol. XIV., pp. 353 ff. (old series).

as a natural science becomes easy. Let us try to see how Herbart presaged such tendencies.

He denies that consciousness consists in a bunch of faculties. Mind persists as a system of concrete relations between its constituent parts. These parts interact mutually, and therefore stand in mechanical relations to one another. As thus related, they constitute a unity of "presentation" which *resists* "arrest of any of its components." Accordingly, "presentations" may form series; these series, in turn, may arrest or strengthen, and shorten or intertwine, mutually. While the simple substance of soul (metaphysical) remains unknown qualitatively, its activities, in its processes of self-maintenance, afford the states of consciousness which psychology studies. In this respect the soul happens to be identical with all other "reals" which, in sum, make Herbart's universe. Therefore, methods peculiar to the positive sciences find application, and mathematical analysis becomes a chief instrument of discovery. Further, the opposition between "presentations" transforms states of consciousness into forces, with the result that a statics and dynamics (mechanics) of mind emerge. It is feasible, accordingly, to *calculate* the equilibrium and movement of "presentations." So, conformably to science, Herbart frames hypotheses and tries to establish them by mathematical methods. He sets himself to show *accurately* how the indeterminate manifold of sensation, as envisaged by Kant, and the multiplicity of ideas as set forth by the faculty-psychology, come to an organic unity in appercipient self-consciousness. In a word, the proper study of psychology is mind which, in turn, consists precisely in those transforming processes known collectively as "apperception." A very apposite delimitation of the psychological field, one would add. And it is both interesting and important to note that, in this theory of apperception, above all else, Herbart continues to speak in contemporary psychological thought. His connection with the modern movement, though by no means clear on the whole, appears in special tendencies. First, in his complete acceptance of the method of regressive analysis; second, in his appeal to experience; third, in the attention which he has compelled to the possibility of mathematical applications in this unstable sphere; fourth, in his gradual drift away from his own metaphysical basis as he wrought to render psychology a natural science—to prove that, in mind, as everywhere, natural law reigns supreme.

Notwithstanding all this, his opposition to anything in the nature of a physiological psychology seems certain. For this curious hesitation reasons must be sought, not in any antagonism peculiar to Herbart himself, as some recent experimental enthusiasts, blind to history, have fondly supposed, but in the general perspective of his age. Like many of his followers, he was a partisan enemy of the speculative philosophy that ruled Germany, and he paid the inevitable price. His judgment on certain scientific developments became warped. He perceived that Schelling's "Naturphilosophie" exercised profound influence upon much of biological science as it then stood. Physiology looked like an ally of idealism, therefore he would exclude it rigidly from psychology, as a sure source of trans-experiential contamination. On this he spoke with no uncertain sound—physiology, as he saw it, was no fit friend for a mathematico-empirical psychology. "Physiology, as an empirical doctrine, has attained a height which nobody can despise. Moreover it proceeds in the light of modern physics. Nevertheless, it has eagerly sucked up, as the sponge sucks up water, that philosophy of nature which knows nothing, because it began by construing the universe *a priori*. Towards this error no science has proved so weak, so little capable of resistance, as physiology."[18] The very end for which Herbart toiled so strenuously is obscured from him by his suspicion of physiological tendencies. Truly the time-spirit plays us humans queer tricks!

Free from these negative considerations, Beneke brought psychology another stage nearer science. He excluded Herbart's metaphysic, demanded concrete treatment of consciousness as the one road to real knowledge, and placed all the other philosophical disciplines in a position of dependence upon psychology. His pivotal doctrine exhibits clearly the possibility of scientific procedure in psychology. It may be put as follows. Experience presents two sides—an "outer" and an "inner." The former consists of sensational phenomena, or, as Hume would have said, "sensations, passions and emotions as they make their first appearance in the soul." The latter includes everything that relates to memory, imagination, thought and ratiocination. Thus science, which deals with the "outer," reaches indirect knowledge of being, while psychology, thanks to its immediate contact with its object ("inner"), arrives at knowledge of true reality. Consequently, by analogy from our own selfhood, we can acquire relatively sufficient knowledge of other men, this sufficiency dwindling, so to speak, as we descend in the scale of existence. Accordingly, positive science is confined to observation, but psychology considers knowledge—an inference from this same observation. Therefore the methods of science apply as much in the one sphere as in the other. In short, consciousness originates the dualism between soul and body, mind and objects. Corporeal processes become conscious in us, and thus fall under direct perception:

> There is no kind of corporeal process which can not under certain circumstances become conscious, and as a conscious thing be perceived by us directly. . . . Such a revolutionary change of a thing usually not a psychical apprehension to a psychical apprehension, would be unthinkable were it the case that their being was in fundamental opposition: we are thus led all the more to the conclusion that both kinds of powers in their innermost nature stand very close

[18] "Werke," VI., p. 65.

to one another, and that for the explanation of their inner coherence and interaction no artificial hypotheses are requisite.[19]

Evidently, then, psychology investigates all that we apprehend through internal perception. If we apprehend anything by external perception, it must submit to transmutation by the "inner," in order to enter into experience as an effective component. I am unable to see that any other meaning can be read into this view than that formulated in the current theory of psycho-physical parallelism. Causal connection between body and mind there is none; and the contrasts in our inner experience of them reside in apprehension, never in actual reality. The plain business of psychology, therefore, consists in applying observation, experiment and hypothesis to the "inner." Just as with science, regressive analysis supplies the methods.

Beneke concludes that psychological processes present themselves as complexes fashioned from four primary factors. These are: (1) The transmutation of sense "excitations"; (2) the formation of new "powers"—analogous, it may be said, to the growth of new tissue; (3) the redistribution of "excitations" (sensuous) and of these new "powers" or products themselves; (4) the interpenetratation of homogeneous products, according to their degree of homogeneity. Obviously enough, redistribution, or transference, within the psychological complex forms the dominant feature; and its forcible similarity to modern energistic conceptions or, as Professor Titchener remarks acutely, "to the process by which one body becomes cooler by communicating heat to another,"[20] needs no comment. Whatever one may think of Beneke's special doctrines, he stands to his material in the attitude of a positive scientific investigator. If Herbart worked like a mathematical physicist, Beneke works like a biologist. Indeed, he reminds one of the French school of so-called "organicists"—Bichat, Claude Bernard, Delage and, perhaps, Roux. I think a specious case could be framed for a parallelism between Beneke's teaching and Claude Bernard's biological conclusion, especially as formulated in the second Leçon in the first volume of his "Leçons sur les Phénomènes de la Vie" (1874), which contains the striking declaration: "la fixité du milieu intérieur est la condition de la vie libre indépendante."[21] Be this as it may, Beneke brought psychology within the purview of scientific inquiry. Like Herbart's, his conclusions might be stigmatized, but that both made preparatory contributions there can be no reasonable doubt. The *attitude* they adopted is of the essence of the matter. And one ought to add that the presence of unconscious or subconscious factors in the physical process, a highly significant phenomenon, follows from the situation as contemplated by them.

[19] "Lehrbuch d. Psychologie als Naturwissenschaft" (1845), Sect. 48.

[20] *Mind*, Vol. XIV., pp. 21–2 (old series).

[21] P. 113.

COINCIDENT ACTIVITIES OF THE EARTH AND THE SUN

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AMONG the inorganic factors by which the fitness of the earth for human occupation is most profoundly influenced, two of the chief are climate, on the one hand, and telluric activity on the other. To climate we owe much of the nature and depth of the soil upon which all life depends; it determines the character of vegetation, and makes possible the vast commerce which consists of the exchange of the vegetable products of one land for the commodities of another; it causes men to engage in different occupations, some, for instance, raising rice in the warm plain of Egypt, and others leading the life of the lumberman or trapper in the cold woods of Canada; and finally climate exerts a profound influence upon human temperament, the inhabitants of the torrid zone, as is generally recognized, being notably less energetic than those of temperate regions. Telluric activity, manifested in movements of the earth's crust, past and present, is equally important, though its effects are not so immediately visible. The ravages of earthquakes and volcanoes, great as they are, fade into insignificance when compared with the stupendous results which have followed from the upheaval of continents and folding of thick strata of solid rock. If telluric processes had not throughout the ages again and again upheaved the crust of the earth, the climatic forces of weathering and erosion would long ago have reduced the original continents to featureless plains of small extent compared with the present great areas of land. There would be no mountains full of minerals, and the use of metals would probably be unknown because none would have been discovered by reason of the enormous depth of soil which would cover the country.

In the study of climate and of telluric activity, attention has till recently been concentrated upon the earth. Within a few years, however, scientists have begun to turn to the sun to see if its changes are in any way connected with changes of climate or with the occurrence of earthquakes and volcanic eruptions. At first the results were negative. Of late, however, students of solar physics have shown that there are now in progress fluctuations of climate which appear to be coincident with variations in the activity of the sun as evinced by the occurrence of sunspots; and the investigations of Jensen, as I shall presently show, seem to indicate an even closer coincidence between solar activity and the occurrence of earthquakes and volcanic eruptions.

Lockyer, Bigelow, Brückner, Clough and others have described climatic cycles averaging 3, 11, 36 and 300 years in length, all closely coincident with variations in solar activity. The 36-year cycle of Brückner is the best established and most easily recognizable. It is now accepted by the majority of meteorologists. It appears to pertain to the continental regions of the earth as a whole, although there are certain parts of the land close to the sea where the changes are the reverse of those in the interior. As to the seas data are not available. In continental regions the temperature is comparatively low at one extreme of the cycle; storms, clouds and precipitation are relatively abundant; storm-tracks of temperate regions approach the equator; snow lies long in winter; glaciers and rivers increase in size; lakes, especially those having no outlets, stand at a high level; and vegetation and animal life are appropriately influenced, as is evident from the time of the ripening of crops, and the expansion of irrigated areas in arid regions. These conditions prevail regularly at an interval of a few years after periods of exceptional activity in the sun. During the period of activity the 11-year sunspot cycle is reduced to 9 or 10 years, and there are other signs of unusual movement in the solar atmosphere. The other extreme of the Bruckner cycle follows a period of comparative inactivity in the sun, and is characterized by climatic phenomena the opposite of those just described. Meteorologists are not yet agreed as to the cause of the climatic cycles, but it seems to be well established that they are somehow connected with the sun.

In regard to the relation of solar activity to earthquakes and volcanoes, there is at present no agreement among students. On the whole, the evidence has seemed to most investigators to indicate that there is no relation. This appears to be largely due to the use of individual cases instead of averages, and to an attempt to find a coincidence between telluric activity, manifested in earthquakes and volcanoes, and *maximum* epochs of solar spottedness. Jensen, however, who has taken up the subject in a comprehensive fashion in volume thirty-six of the "Proceedings of the Royal Society of New South Wales," has come to a different conclusion. He has compiled a list of notable earthquakes and volcanic eruptions from 1783 to 1902. Each occurrence has been assigned a value of one, two, three or four, according to its severity, and all the earthquakes and eruptions for the whole series of years have been plotted as shown in Fig. 1. Having in this way obtained a graphic representation of the intensity of telluric activity in each year, Jensen added a curve showing the occurrence of sunspot maxima and minima. An inspection of the diagram thus obtained shows that earthquakes and volcanic eruptions are most frequent and most intense during the years shortly before and after sunspot minima.

In order to estimate the reliability of Jensen's conclusion, it is necessary, first, to eliminate the personal equation by comparing his data with another set compiled independently; and, second, to eliminate accidental or sporadic occurrences and faulty observations by an appeal to averages. It has been possible to accomplish the first result by means of data which Mr. Robert W. Sayles, of Harvard University, has kindly put at my disposal. In the pursuit of certain researches having no immediate connection with the problem in hand, he had prepared a table showing the years of occurrence of notable earthquakes and eruptions from 1755 to 1902. He had divided the years into three classes according to the severity and number of the phenomena of both sorts in each year. He has kindly prepared the accompanying diagram (Fig. 1), showing, on the one hand, the years of telluric activity by means of the row of dots at the bottom, and, on the other, the number of sunspots by means of the wavy line. The open circles indicate years when notable earthquakes or eruptions occurred, although not in large numbers, nor of exceptional severity. They are reckoned as unity. The solid round dots represent years of greater severity than the preceding, and are reckoned as having a value of two in computation. The solid squares indicate extreme severity, and are reckoned at three. To the diagram as prepared by Sayles, I have added Jensen's data, as appears in the small rectangles above the sunspot curve. Jensen, unlike Sayles, has separated earthquakes and volcanic eruptions. Earthquakes are shown above the heavy horizontal line, and eruptions below. The size of the rectangles indicates Jensen's estimate of severity and frequency combined. For convenience of reference I have added the appropriate numerals.

The data of Sayles and Jensen supplement each other admirably. Neither investigator lays claim to absolute completeness in his data; but, on the contrary, both express regret that they have not been able to obtain fuller information. Nevertheless neither appears to have omitted any phenomenon of first-class importance. The method of compilation was quite different in the two cases. Sayles lays special stress upon the severity of individual earthquakes or eruptions; while Jensen emphasizes the total number of occurrences in a given year. The two sets of data were prepared without reference to each other; and different sources of information were evidently used, as appears from the relatively large importance which Jensen, an Australian, naturally assigns to the phenomena of Oceania. For instance, to illustrate the difference in the point of view, Jensen gives to 1835 the value of 6; while Sayles makes it one of the severest years, which on Jensen's scale would give it a value of 20. Again Jensen reckons 1855 at 17, while Sayles put it in his lowest class which would give it a value of only 7. The next year, on the other hand, is reckoned by Jensen at only 4, and by Sayles at 14. Other years, such as 1873–4–5–6 and 22 others are given values of from 1 to 16 by Jensen, but are not mentioned by Sayles; while the latter gives an open circle to 1803, 1805, 1853, 1861, 1863 and 1885, although Jensen does not assign them a value of even one. Other discrepancies might be mentioned. They are natural, indeed unavoidable, in a subject where there is so much opportunity for the personal equation, as well as for diverse authorities. A man's estimate of the severity of an earthquake or eruption is sure to depend largely upon the vividness of the account which he happens to read. Hence the great value of having two independent sets of data compiled for different purposes by men living at the antipodes, New England and New South Wales. The discrepancy in the two sets of data is an advantage because the one supplements the other, and because where the original sources of information are so diverse, the harmonious result derived from averages is highly remarkable. It can not be the result of chance.

Inspection of Fig. 1 shows that according to both Sayles and Jensen periods of *minimum* sunspots are times of *maximum* seismic and volcanic activity; whereas at periods of maximum sunspots, telluric activity almost ceases. There are certain glaring exceptions, such as 1883, or 1906 which does not appear in Fig. 1; but it should be noted that in 1883 the sunspot maximum was only about two thirds as high as the average. In order to estimate the true importance of such exceptions, I have plotted the curves shown in Figs. 2–5, showing the relative frequency and intensity of telluric activity in years of sunspot minima as compared with other years. Figs. 2 and 3 show the frequency of years in which one or more notable earthquakes or eruptions—combined in the case of Sayles, separate in that of Jensen—have occurred at the sun-spot minima and during the intervening years. To illustrate concretely, it appears in Fig. 1 that out of fourteen years of minima included in the period covered by the investigations of Sayles, 11, or 79 per cent., have, according to him, been characterized by notable earthquakes or eruptions. Out of the thirteen years immediately preceding a minimum only 5, or 38 per cent., have had noteworthy seismo-volcanic phenomena; out of those preceding a minimum by two years, 6, or 46 per cent., and so on. Of course, the curve soon comes to zero at either end, because, on an average, five or six years before or after a minimum we come to a maximum separating one wave of the sunspot curve from another. To illustrate again, 1867 was a minimum year, and has a solid circle below the sun-spot curve and two rectangles marked 2 and 6 above it. Therefore in calculating the data for the three curves of Figs. 2 and 3 it counts one in every case. So too does 1868, although it was a year of greater severity as is indicated by the solid square below the curve and the rectangles marked 12 and 8 above it. The year 1869, however, having only a single rectangle with a value of two, counts only in the computation of the data for the solid line of Fig. 3. 1870, on the other hand, is reckoned as one in computing the curve of Fig. 2 and the dotted line of Fig. 3. With 1870, which was a maximum year, we cease to count the years as being after the preceding minimum. 1871 is reckoned not as four years after 1867, but as seven years before the minimum of 1878, and so forth. By adding the figures for all the sunspot waves, and plotting the results, we get the simple frequency curves of Figs. 2 and 3. Figs. 4 and 5 are derived in the same way, except for one thing. Instead of reckoning each year of the occurrence of earthquakes or eruptions as having a value of only one, each is reckoned according to the value given it by Sayles or Jensen, respectively, as shown by the character or size of the spots and rectangles of Fig. 1. An inspection of the four curves of Figs. 2 to 5 shows that they agree in essential points. Each of the six curves, two for Sayles, and four for Jensen, has a pronounced maximum at or within a year of the time of sun-spot minimum. That is, when sunspots are fewest, earthquakes and volcanic eruptions are most numerous and most severe.

The four curves of Figs. 6 to 9 on the right-hand side of page — were drawn in exactly the same way as the four which lie beside them (Figs. 2–5), except that the sun-spot *maxima* were used as the reference points instead of the minima. They are introduced by way of contrast. It is evident that telluric activity is weak at times of sun-spot maxima. All the curves of Figs. 2 to 9 show the lack of symmetry characteristic of sun-spot variations. The lapse of time from maximum to minimum is greater than from minimum to maximum.

Having seen that there is a coincidence of some sort between sun-spot minima and seismo-volcanic maxima, the next step is to compare the mean sun-spot curve from maximum to maximum with the mean seismo-volcanic curve for the same period. The mean sun-spot curve is, of course, easy to obtain. Figs. 10 to 13 show the first stages in the construction of the mean seismo-volcanic curve. The time from one sun-spot maximum to the next is divided into eight periods as follows:

1. The year of maximum spots.
2. The year succeeding that of maximum spots.
3. An intermediate period of decreasing number of spots,—average length about 3½ years.

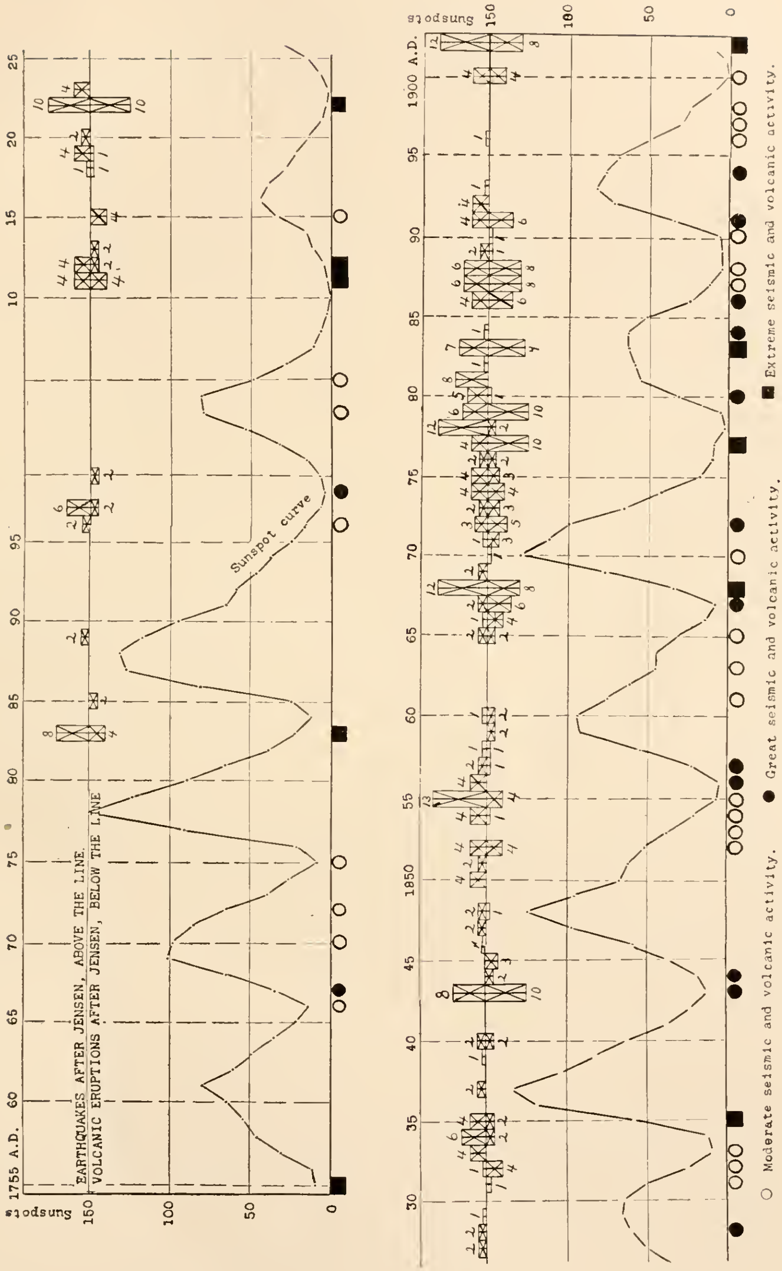
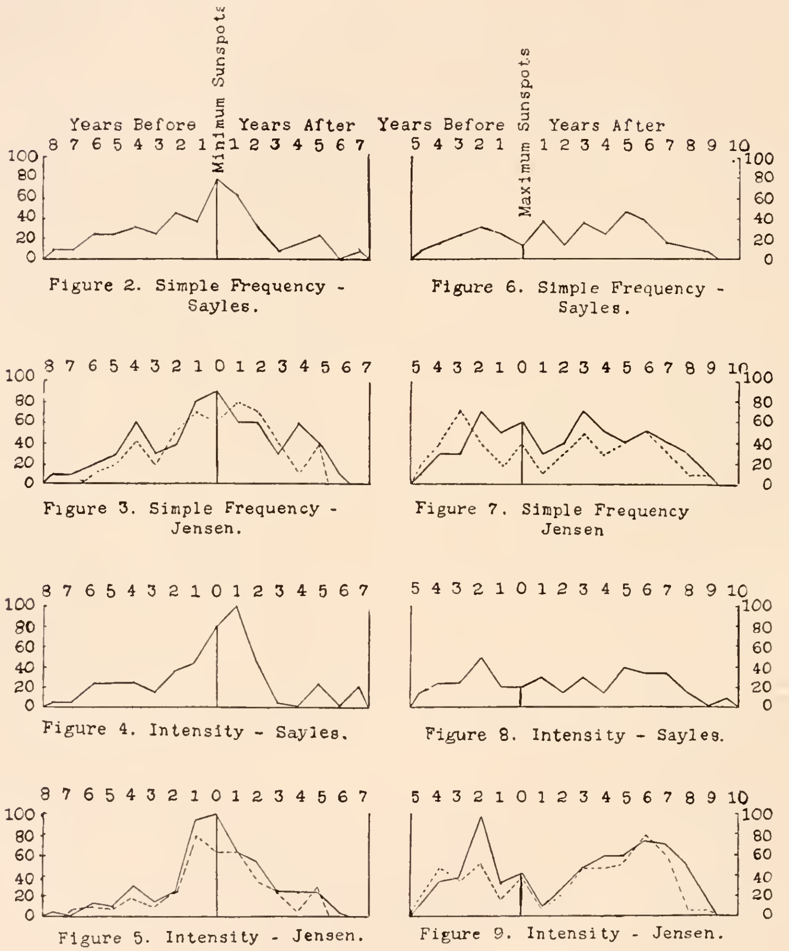


FIG. 1. THE RELATION OF SUNSPOTS TO EARTHQUAKES AND VOLCANOES. (After Sayles.)

4. The year preceding that of minimum spots.
5. The year of minimum spots.
6. The year succeeding that of minimum spots.
7. An intermediate period of increasing number of spots,—average length about 1½ years.



Figs. 2–9. The relative Frequency and Intensity of Seismic and volcanic Phenomena at Periods of Sunspot Minima (2–5) and Maxima (6–9). The numerals above the diagrams indicate years, those on the sides, percentages. In the diagrams compiled from Jensen's data the full lines indicate seismic phenomena, and the dotted lines volcanic phenomena.

8. The year preceding that of maximum spots.

The irregular periods numbered 3 and 7 are necessary because of the variation of the length of the sun-spot cycle. Number 3 may vary in length from 1 to 7 years, and number 7 from 0 to 3.

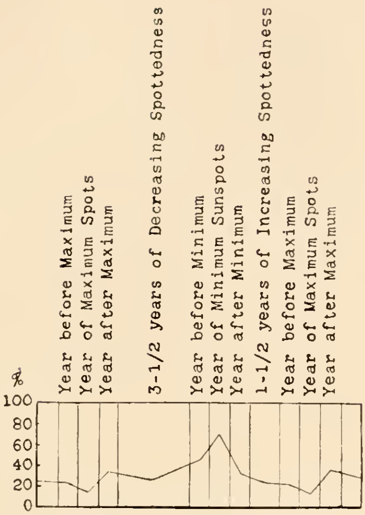


Figure 10. Simple Frequency - Sayles.

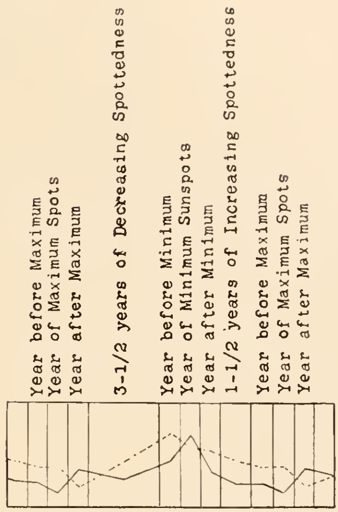


Figure 14. Simple Frequency.
____ Sayles' curve of Fig.10.
----- Mean of Jensen's two curves of Fig.11.

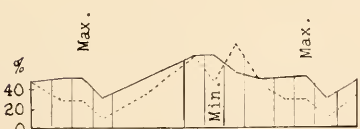


Figure 11. Simple Frequency - Jensen.
____ Earthquakes, ---- Volcanoes.

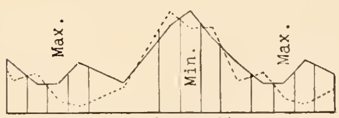


Figure 15. Intensity.
____ Sayles' curve of Fig.12.
---- Mean of Jensen's two curves of Fig. 13.

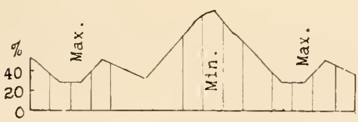


Figure 12. Intensity - Sayles.

Fig.16. Mean Frequency and Intensity
____ Frequency, mean of Fig.14.
---- Intensity, mean of Fig.15.

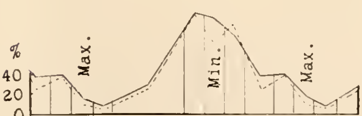


Figure 13. Intensity - Jensen.
____ Earthquakes, ---- Volcanoes.

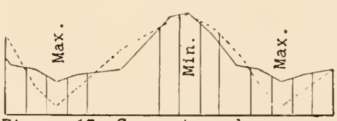


Figure 17. Sunspots and Seismo-volcanic Activity.
____ Seismo-volcanic curve, mean of Figure 16.
---- Mean Sunspot Curve since 1755, inverted.

For each of the eight periods of the sun-spot cycle, the percentage of years of seismic and volcanic activity has been calculated from the data of Fig. 1, as shown in the table at the end of this article, and has been plotted in the frequency curves of Figs. 10 and 11. For Sayles, 13 complete sunspot cycles are available, and for Jensen, 10. In the same way the average intensity of the phenomena of the years of each period has been calculated and plotted in Figs. 12 and 13. In order to obtain the mean curve it is necessary to combine the six shown in Figs. 10 to 13 into one. The first process is the combination of Jensen's four curves into two which shall be comparable to the two of Sayles. This is done in Figs. 14 and 15. In Fig. 14 the solid line reproduces Sayles's line of Fig. 10 directly, while the dotted line gives the mean between Jensen's two curves of Fig. 11. Thus we have two mean seismo-volcanic frequency curves. In the same way, in Fig. 15 the solid line reproduces Fig. 12, and the dotted line gives the mean of the two lines of Fig. 13; and we have two mean seismo-volcanic intensity curves. In these curves, as in the others, percentages are used, so that when diverse phenomena such as frequency and intensity come to be compared and averages computed, each receives the same weight. In Fig. 16 the frequency curves of Sayles and Jensen shown in Fig. 14 are combined into the solid line and the intensity curves of Fig. 15 into the dotted line. In order to make the two curves comparable the maximum in each case has been reckoned as a hundred. As a result of the combination of the data of our two authorities, the personal equation is largely eliminated. It will be noticed that the curves of Fig. 16 are much smoother than those of preceding figures. This is especially true of the frequency curve where there is least liability to errors of judgment. Finally, in Fig. 17 the two curves of Fig. 16 are combined into one, shown by the solid line. This represents the net result of Sayles's data as to the combined seismic and volcanic frequency and intensity of 13 complete sun-spot cycles, and of Jensen's independent data as to the uncombined seismic and volcanic frequency and intensity of 10 complete sun-spot cycles. The dotted line in Fig. 17 is the mean sun-spot curve derived from Fig. 1, and calculated and plotted in precisely the same manner as the six curves of Figs. 10 to 13 from which the mean seismo-volcanic curve is derived. For the sake of convenience in comparison, the sun-spot curve has been plotted with the minimum at the top.

The resemblance between the mean sun-spot and mean seismo-volcanic curves is extraordinary. The maximum of the one occurs at the same time as the minimum of the other, and in both cases there is a steady progress from maximum to minimum and back. If our terrestrial data of earthquakes and volcanoes were as complete as our solar data of sun-spots, it is probable that the resemblance between the two curves would be still closer. It may be that the occurrence of earthquakes and eruptions lags somewhat behind the change in the number of sun-spots, but the lag is so slight that it does not appear where the unit of measurement is a year, although it might if the unit were a month. It seems to be impossible to avoid the conclusion that the marked coincidence between telluric and solar activity indicates a relation of some sort between the internal phenomena of the earth and the sun.

As to what that relation may be we have as yet no clue. The best that we can do is to speculate. It may be, perchance, that there is some cosmic source of energy as yet unknown, which pulsates through the universe causing both the earth and the sun to respond, each according to its kind. Possibly changes in the amount or in the nature of the energy emitted by the sun engender corresponding changes in the earth in some manner as yet beyond our ken.

At the present time, as we have seen, changes in the sun appear to be coincident with climatic and telluric changes in the earth. So far as we can judge, the climatic changes, though on a very small scale, seem to be of the same nature as the great climatic changes of the various glacial periods of earlier geological times. The telluric changes, also on a very small scale, are apparently of the same nature as the great movements of the past by which mountains have been formed and continents uplifted. It is notable that according to the general opinion of geologists the three best known and most severe climatic changes through which the earth has passed have been closely associated with profound modifications of the earth's crust. The glacial period which occurred just before the Cambrian period, far back near the beginning of legible geological records, was followed by a great change in the distribution of land and sea. Again after the prolonged period of comparative stability known as the Paleozoic era there ensued the severe Permian glaciation composed of many glacial epochs separated by warm epochs. At approximately the same time, or shortly afterward, there was a great uplifting of the continents and the formation of mountain ranges such as the Appalachians. Finally the last great glacial period, that of the Pleistocene and Pliocene was also a time of great mountain-building, when the Alps, the Sierra Nevadas, and the Himalayas received a marked uplift giving them their present altitude.

It thus appears that in geologic history the greatest known climatic changes have been closely associated with remarkable telluric changes. It appears that at present climatic and telluric changes on a small scale are coincident with or follow closely upon changes in the sun. The question at once arises whether there may not have been a similar coincidence in the past. No attempt can be made to answer the question as yet, but it opens a most fascinating field of speculation and of investigation. If the activities of the earth and of the sun are related to one another in any such manner as is suggested above, the study of the one will add vastly to our knowledge of the other. An examination of solar changes, on the one hand, may enable us to foretell something of what is about to occur upon the earth. A careful reading of the geological history of the earth, on the other hand, may disclose the history of the sun for millions of years past, and may shed light upon the fascinating problem of the thermal history and ultimate destiny of the body which, as knowledge increases, appears more and more to be the arbiter of terrestrial life.

Reference Table showing the Data used in the Construction of Figures 2–17

Percentage of Years with Earthquakes or Volcanic Eruptions per Sayles	Percentage of Years with Earthquakes per Jensen	Percentage of Years with Volcanic Eruptions per Jensen	Average Seismic and Volcanic Intensity per Sayles	Average Seismic Intensity per Jensen	Average Volcanic Intensity per Jensen	Average Number of Sunspots	
15	50	30	0.31	0.70	0.40	99	(1) Year of maximum sunspots.
38	30	10	0.54	0.40	0.33	83	(2) Year after maximum.
28	51	36	0.33	1.30	0.95	44	(3) Three and one half years of decreasing spottedness.
46	73	73	0.92	4.17	4.10	15	(4) Year before minimum.
71	73	45	1.07	4.00	2.73	7	(5) Year of minimum sunspots.
36	55	82	0.82	3.27	3.55	19	(6) Year after minimum.
24	47	42	0.52	1.58	0.89	40	(7) One and one half years of increasing spottedness.
23	50	30	0.31	1.70	1.50	79	(8) Year before maximum.

SPRINGS AS A GEOGRAPHIC INFLUENCE IN HUMID CLIMATES

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IN the arid southwest parts of the United States, the crude water signs of the Indians have often pointed the white man to a spring. The government topographic maps covering sections of this region of sparse rainfall give the location of many springs. Throughout the longer-known and more-traveled desert areas of the world, the few oases have fixed the routes taken by caravans. Numerous books are available detailing facts that bear on the geographic influence of springs

A RECONNAISSANCE CONTOUR MAP in which the altitudes were ascertained by working aneroids in pairs, a method explained in the *Journal of Geology*, Vol. XV. (1907), p. 492. In this area there are 203 dwellings, 148 of which are located at springs.

A PRIMITIVE LOG HOUSE nestled among the trees marks the location of a constant spring.

in arid climates. But into whatever land man has gone, humid as well as arid, springs have had a part in his activities. So far as America is concerned, I am not aware that a quantitative study of the influence of springs in humid regions has been undertaken.

While mapping the stratigraphy of an area of approximately 25 square miles in central Ohio, where the annual precipitation is about 40 inches, the influence exercised by springs was given particular attention. In this area the upper formations of the Mississippian, and the lower of the Pennsylvanian periods come to the surface. The vertical series of rocks involves two horizons of coarse clastic sediments, the Black Hand of the earlier period, and the Sharon member of the Pottsville, which is the lowest formation of the later period. The Black Hand overlies the Cuyahoga, which in central Ohio "is composed largely of bluish and grayish shales and buff sandstones."[1] Subjacent to the Sharon is the Logan formation consisting chiefly of "buff arenaceous shales to thin bedded sandstones."[2] The Black Hand is a massive sandstone, locally conglomeritic; the Sharon is less massive, and locally coarser; this characterization of these two formations applies specifically to the area studied. While neither of these sandstone formations overlies impervious beds, yet in themselves they are variable in texture and structure, and the region is so maturely dissected, that conditions are very favorable to the development of springs. Furthermore, the Logan also contains beds that are water-bearing.

The early settler in agricultural lands found a spring, if possible,

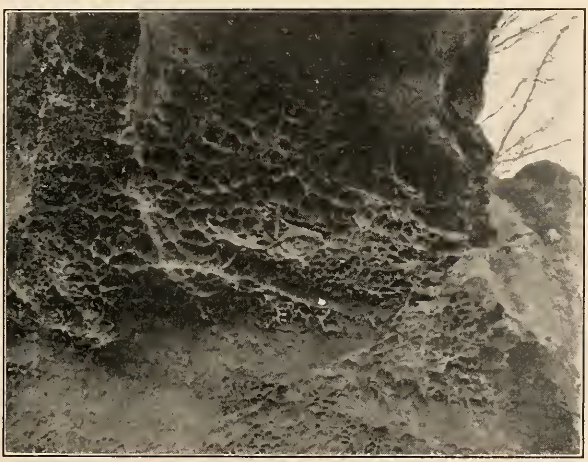
[1] Charles S. Prosser, *Journal of Geology*, Vol. IX. (1901), p. 220.

[2] *Ibid.*, p. 231.

and then built his log house. Others coming into the region made similar locations. Settlement generally moved along streams, since in the absence of roads valleys are more accessible. If the valley has been developed in water-bearing formations, which are not much tilted, springs border the bottom land on either side. Both topographic convenience and the presence of water tended to confine the earliest habitations to the valleys. Later settlers spread over the intervalley areas, building their houses in proximity to springs.

Primarily the highways lead from house to house; eventually, however, several factors become operative before the roads are permanently fixed. In the case of a valley having a commodious floodplain, but not extensive enough to warrant the maintenance of roads on each side, the slope bearing the better springs was normally the decisive factor; the homes on the opposite side would be approached by fords and lanes, or by only the latter if located near a transverse highway. In the uplands the permanent lines of traffic appear to take courses that will accommodate the greatest number without making too great sacrifice in distance; even then some dwellings are isolated. The isolation may continue but one generation, or until the desire to live on the highway overcomes the convenience of water and the associations of the hearth; the latter factors have prevailed wherever we see an isolated frame house, whereas a deserted log cabin means the dominancy of the former.

Moreover, the intervalley highways sometimes exhibit an economic influence. When the area is heavily timbered, and lumbering rather than agriculture is the initial occupation, the roads made in connection with logging and milling may become permanent. For example: North of Wilkins Corners (see map) the second highway leading west ascends about 160 feet in one half mile; this road parallels a valley a



THE IRON CONTENT OF THIS SHARON ROCK induces the "honeycomb" effects in weathering, and also makes the springs less desirable.

THE GENTLE SLOPES OF THE LOGAN FORMATION AFFORD GOOD FARMS, but few springs for dwellings. Twice as many houses are found along the lower contours of the Black Hand formation where water is plentiful.

few rods to the left, where the same horizontal distance involves only half the grade; the original highway did follow the valley, connecting the two houses. But log-haulers from the wooded upland located their main road where it would command as much of the area as possible, approaching it by spurs along contours. This traffic fixed the road where it is, though it has never led directly to a dwelling; property complications diverted the second house up the valley to it, the original roadway being abandoned. A similar influence in highway-location due to mining operations is seen one and one half miles west of Mary Ann Furnace in the road trending southwest from the one leading to Wilkins Corners. Some fifty years ago a vein of coal on this slope was worked for local use, and was approached from the west, thus opening a highway that has served little use since.

It is evident also that so far as the intervalley roads are concerned, the topographic factor made slight appeal to the locating engineers, an ox-team and its driver. If the most direct line between houses, *i. e.*, between springs, crossed a sharp hill, the highway went directly over rather than follow a contour, or take even a gentler, if slightly longer, grade. I have noted several places where in the past decade these sharp grades have been removed by a detour, but two generations had dragged themselves wearily over the hill.

The convenience of good water, or of rich bottom lands in the valleys, factors that would seem to have much weight with the early settler in choosing a location, is of secondary importance when opposed to an inherited topographic proclivity. A man reared among hills, however barren, has a latent tendency to plant his new home in similar topography. This bias, developed through environment, whether inherited or acquired by the individual, is illustrated in the choice of lands made by Welsh immigrants who came into Licking County, Ohio, early last century; they passed by thousands of acres of lowlands, the richest in the state, and selected farms in a rugged portion of the county, still owned by their descendants, and even now designated "The Welsh Hills."

But in the region to which special study was given, the geographic influence of springs is obvious. There are 203 houses in the township, 148 of which are built at springs; some of the fifty-five using wells formerly depended on springs. Both the horizontal and vertical distribution of these dwellings is largely a matter of stratigraphy of which the springs are a manifestation. It should be noted, however, that the localization of houses near Mary Ann Furnace is due to the fact that over sixty years ago iron ore, found in the neighboring hills, was reduced here; stoves also were manufactured at this place. The furnace was destroyed in 1853, but the houses are still in use.

Over fifty per cent. of the dwellings with springs are in the horizon

THE TINY RILL OF A SPRING THAT HAS ALREADY DEVELOPED A SMALL BASIN.

of the Black Hand formation, which borders the floodplains of all the valleys, a distribution made possible because the formation has an eastern dip of about twenty-five feet per mile. The springs in the Black Hand are numerous and copious, partly because of the thickness

THE BLACK HAND FORMATION is generally a coarse, irregularly bedded sandstone, yie.ding a copious supply of spring water.

and texture of the formation, also because of its subjacency to horizons that carry water freely.

In the Logan formation, I have mapped thirty houses with springs. There is doubt concerning a few of these, an indefiniteness occasioned by the absence of contacts. The Logan sediments suffered erosion contemporaneously with Pottsville sedimentation; furthermore, the Logan, in comparison with its contact formations, the Black Hand and the Sharon, weathers easily, producing gentle slopes. These two conditions make it doubtful about the exact horizon of a spring near either the top or the base of the Logan.

Sawed Shingles and a Few Boards are used in lengthening the Years of Service of this Rough-hewn Log Spring house.

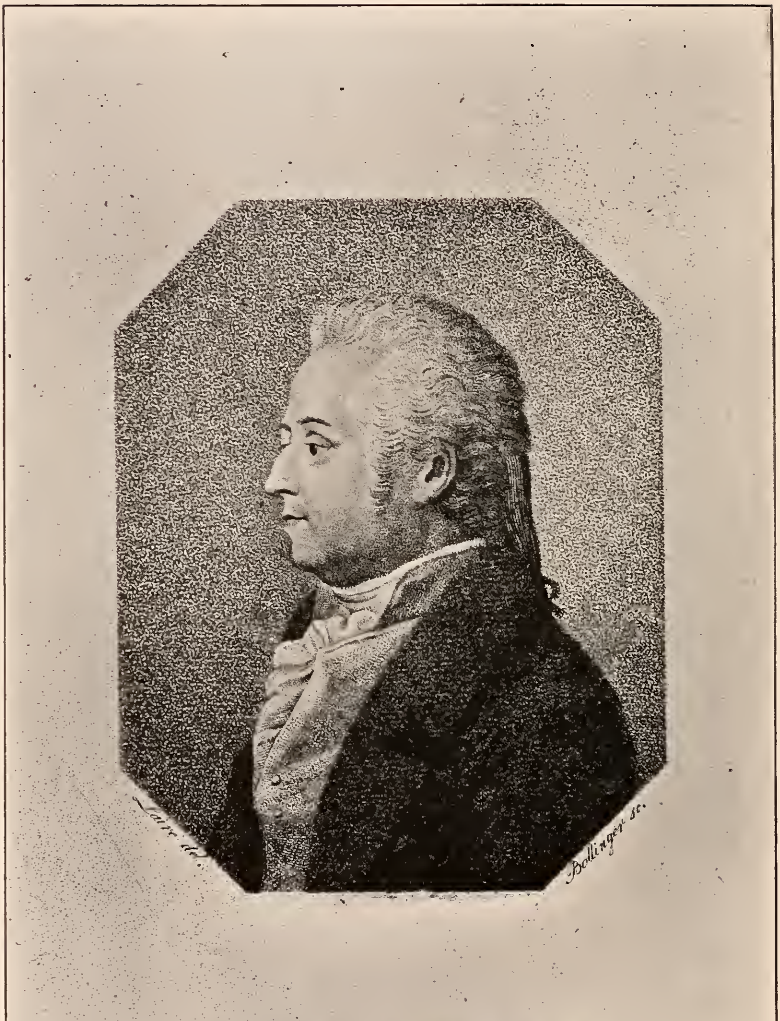
Slightly less than seventeen per cent. of the houses with springs are found in the Sharon. The areal extent of all the exposed formations diminishes vertically, hence the number and the volume of the springs decrease; the value of the land for farming also decreases with altitude. A further fact concerning the springs of the Sharon is their content of iron, making them less desirable than springs in either of the lower formations.

A Mature Stage of Erosion is a Condition favorable to Numerous Springs.

The township contains no extensive areas of outcropping coal measure or Pennsylvanian formations, save in the south central portion; elsewhere disintegration has left only outliers. In the area west of Mary Ann Furnace, covering several square miles, and another along the eastern border of the township, there are eighteen houses, three of which, now occupied, have springs. For the entire township, the average number of houses per square mile is about eight; for the horizon of the coal measures, it is less than two. That springs are rare is not the sole cause for the discrepancy; the bleakness of the upland, and the unproductiveness of the soil are contributory factors.

About ten per cent. of the homes with springs are built on glacial deposits. The drift is localized chiefly in the valleys. The ice-sheet covered approximately two fifths of the township, but left scarcely a veneer of drift on the intervalley areas. While fourteen springs have been mapped as belonging to the drift, it is quite probable that a good fraction of these are fed by water courses from the Black Hand formation. Of the wells noted, fifty-six per cent. are in glacial deposits.

Still another evidence of the influence due to springs is seen in the fact that of the eight deserted houses in the township one is in the Black Hand formation, one in the Logan and six in the coal measures, the horizon practically without springs. It is noted also that twenty-two per cent. of the dwellings are off highways, an isolation due entirely to springs. Furthermore, dairying has always been carried on in this region because in the summer season the springs furnish cool water for handling milk.



JOHANNES v. MÜLLER.

JOHANNES MÜLLER[1]

By Dr. PHILIP B. HADLEY
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IN the present day when the individual laborer in the fields of biology is so often lost in the flood of new facts which is continually being poured into the archives of the science; when a narrow specialization and very definite concentration of activity are the primary condition and means for furthering the highest interests of the science as a whole, and when the difficulty is ever increasing, to hold in the foreground the larger and more general problems of biological significance, it may not be altogether inappropriate to recall—we might almost say revive—at times, some of the monumental figures whom the history of every science, at rare periods, brings forth, and to learn once again our debt to them.

That the times are past when it is permitted a single individual to survey, in full understanding, the broad fields of activity in the realm of general biology must assuredly be considered as a sign of advance. We may even remark that the gradual expansion which physiology alone has undergone during the last half century, in passing beyond the confines of a unitary science and in trespassing—perhaps with right—upon the fields which had at one time belonged to other realms, is a necessary consequent to the death of the last great ruler of the science. For these reasons alone it may be of interest and of profit to recall the single instance of a man who, during his years of activity, so deeply influenced the drift of physiological thought; and after whose death, the overgrown and no longer self-containing science of physiology burst like a great stream at its mouth, by many and devious channels to reach the sea.

Johannes Müller was born in the city of Coblenz on the fourteenth day of July, 1801, the son of Mathias Müller, a shoemaker. Although a man of small means, the father determined not to deny his son the advantages of a fair education, and accordingly the young lad was sent to the Jesuit school in the place of his birth, then under French control. Here he remained for eight years, pursuing a study of the classics and mathematics and gaining the foundation of that knowledge of Greek used so brilliantly in after years in the translation and

[1] On the above subject the writer would acknowledge the especial value of two German works from which he has freely borrowed: A comprehensive treatise by DuBois Reymond, "Gedächtnissrede auf Johannes Müller"; and a brief paper by Max Müller, in *Westermann's Monatshefte* for July, 1901. The present paper was first presented in a course of biological seminars at Brown University.

commentation of Aristotle. A few years later we find him at the Gymnasium, where, in spite of the old scholastic system of teaching, he took a deep interest in the study of the animal and plant worlds—an interest which was no doubt stimulated by the reading of Goethe, whose works were a source of great delight to young Müller. During this period there also appears to have developed in him that rich gift of imagination which, as one of his biographers says, is so necessary not only to the poet, but also to the natural investigator. In his later work on the "Phantasmal Phenomena of Vision," Müller tells us how, as a boy, he perceived in the crumbling walls of a neighbor's house all sorts of odd and fantastic figures and faces.

At the age of seventeen, Müller left the Gymnasium and, having served one year in the army—as was customary with the youths of his station—he entered, at the age of eighteen, the University of Bonn, which had just been founded. As has been the case with so many natural scientists, here Müller at first hesitated in making his decision between the church and medicine. Born as he was of Roman Catholic parents and nurtured in the Catholic faith by a strongly believing mother, it is not strange that, even as a child, he manifested a desire to enter the priesthood. But the decision was soon made. For three days, so we are told, young Müller closeted himself in his room in order that he might deliberate. At the expiration of this time he made known his decision to a friend in these words: "I am determined. I shall study medicine; for I know what I have and whom I serve."

While at the University of Bonn, Müller's career was characterized by an intense application to study. He maintained, however, a constant exercise of independent thought, and manifested a keen relish for original investigation. Here he initiated, even in the first year of his studies, a series of experiments upon the "respiration of the fœtus," a subject in which a prize had been offered by the university. This prize Müller secured when at the age of nineteen. In connection with the work, a story which a friend of Müller has made known, is characteristic of the young investigator at this time. He had once started upon a journey on horse to Arrthal and was but a short distance on the way when, by the roadside, he espied a pregnant cat. He immediately gave chase, captured it and, for the time being postponing his journey, carried the animal back to the university, where, by Caesarian section, he deprived it of its young in order that he might consequently solve some point in his first problem of investigation.

During the early part of his period at Bonn, although as a student he was most intent upon his work, he was not wholly indifferent to the general yearning for constitutional freedom which was pervading the thought of the middle and lower classes throughout the German states after the expulsion of the French. The movement towards a student alliance was then at its height, and this seized strongly upon Müller, who, as we learn, took a leading part in that rather enthusiastic association in which the academic students still cherished hopes of a German unity.

Even these early investigations of Müller were bringing him to the notice of many of the scientific men of his time. On the occasion of the publication of his work on the "Laws of Animal Motion," Oken, the then famous natural scientist, expressed his high approval together with the wish that Müller might be permitted to devote himself purely to natural science. Of this course of action, however, there seemed at that time little prospect. After the death of Müller's father, the small family inheritance lasted but a short while; and from this time until the dawn of his European fame Müller appears to have been constantly troubled with the distressing problem of obtaining the necessary funds for the continuance of his labors; and often even with the question of obtaining food. But in spite of the difficulties which his financial condition enforced upon him, this was on the whole a gay time. The thoughts of the wide possibilities of his chosen vocation appear to have maintained the spirit of the youth, and the unquenchable thirst for knowledge and recognition was gratified at every spring which philosophy, literature, theoretical natural science and careful observation offered. It was also here and during these early years of his study that Müller contracted the spirit of the *Naturphilosophie,* from whose grasp he was freed at a later date through his contact with Rudolphi at Berlin.

When we consider the trying conditions which surrounded Müller in this period of his life, it must be considered most fortunate that there stood at the head of the Prussian ministry a man who, more than any other, appears not only to have recognized Müller's genius, but also to have had the ability to loosen the fetters which bound up Müller's great gifts. This man was the Minister von Altenstein; and it was he who, by securing a generous government stipend, made it possible for Müller to spend two years—from the spring of 1823 to the autumn of 1824—in furthering his scientific studies at Berlin, where Müller shortly passed his examination for the license to practise his profession of medicine.

It was here that Müller had the great good fortune to become the favorite pupil of Rudolphi, who at that time was the most formidable enemy to subjective speculation in biological science, and who already had begun to base physiology—rather exclusively, perhaps—on the actual study of animal structure. It was Rudolphi, moreover, who had the liberality to place at Müller's disposal his laboratory, his apparatus, his library, and what was still more advantageous, his constant oversight and advice. Of the encouraging aid which he received from that excellent master, Müller afterward spoke in the most grateful terms, and declared that it was through the influence and example of Rudolphi alone that his own scientific pursuits were afterwards turned so fully in the direction of comparative anatomy.

At the expiration of his two years of labor, and immensely enriched in all the fields of natural science, Müller again returned to Bonn, and in 1824 was enrolled as academic lecturer in comparative anatomy and physiology. Two years later, when but twenty-five years old, he was made professor extraordinary in the same branch of science.

The epochs in his activity in investigation which immediately followed upon his return to Bonn have well been called by DuBois Reymond the *subjective physiologico-philosophical period.* The literary landmarks of this period in Müller's career are two works: First, "On the comparative physiology of the sense of sight in men and animals, with researches on the motions of the eyes and on the sight of man"; second, "Concerning the phantasmal phenomena of vision: a physiological research dealing with the physiological evidence of Aristotle concerning dreams, the philosophies and the arts."

In the former of these two works we find recorded that excellent discovery that the sight of insects (which possess facet-eyes) must be conceived of as a mosaic interpretation of objects; that is, the pictures which the insects themselves see are placed together as in the form of a mosaic. In the second work regarding the "Phantasmal Phenomena of Vision," Müller took up a study, the idea of which reached far back into his earliest youth, when he was accustomed to give free play to his fancy in imagining strange shapes and figures on the plaster-scarred walls of the old buildings. These fanciful appearances, which thus early became so familiar in the imaginings of his boyhood, he submitted in maturer years to searching philosophic scrutiny; and the work in which they are described and discussed is a charming yet masterly application of experiment in anatomy, physiology, physics and psychology. Through the medium of these scientific principles Müller explained the seeing of devils and spirits; the friar, who, after long hours of supplication, sees the desired consecration in the form of a shining cloud; the superstitious, to whom the tempter appears as an evil spirit: these phenomena were for Müller only the results of the passion-aroused conditions in the material substances of their sight.

Of all Müller's labors at this time, greatest importance must be attached to his work in elucidation of the laws of the specific energy of the sense organs. With ingenious experiment he worked out the general law that, in whatever manner a sense organ may be stimulated, it always answers to our consciousness by the method peculiar to it. It was from these and other related investigations that Müller deduced many of his philosophical principles: For instance, that we can not understand truly the things of the world outside of ourselves, but are cognizant only of the changes brought about in the sense-substance by the thing itself. From these considerations we can readily understand how Müller was led to adopt the view of subjective idealism.

During this period at Bonn, however, the duties which, as a teacher, Müller imposed upon himself, together with the unremitting employment in the lines of his original investigations with all its concomitant labor and thought, had induced, soon after his marriage in 1827, a state of mental and physical exhaustion. Upon the eve of a nervous break-down he secured a leave of absence from the university and with this a recompense of two hundred thalers which made possible for him a journey up the Rhine and through southern Germany. On this trip he was accompanied by his newly married wife. Soon, however, with bettered health he returned to Bonn, where in 1830 he was made professor ordinary.

This event marks the end of what we may term Müller's fiery subjective period, and the beginning of his great *objective physiologico-anatomical period,* which covered the years of his most brilliant achievement. He was now devoting himself to many branches of scientific work, especially to his morphological studies. Through his anatomical and systematic researches on the scorpion and spiders, he showed himself worthy to be ranked among the first zoologists of his time. In his work, "On the Development of the Reproductive Organs," which appeared a few years later, Müller traced the development of these organs in man and in animals. Coincident with this he was pursuing his researches into the development of other organs, and produced his treatise on the secreting glands. In this excellent work the phylogenetic and ontogenetic development is considered in both man and the lower animals.

In the latter part of Müller's life at Bonn occurred two significant physiological discoveries: First, he definitely proved, through a convincing series of experiments on the frog, the view which had been first announced by the Englishman, Charles Bell, in 1811: that the anterior roots of the spinal cord are motor, and that the posterior roots are sensory in function. In reality this experiment was simple enough. In a frog Müller cut on one side the anterior and on the other the posterior nerve roots of the spinal cord. On the side on which the posterior roots were cut the frog was wholly insensible, while the side on which the anterior roots were cut remained quite paralyzed. This experiment awakened in the scientific world of that time a storm of applause. The fortunate experimenter journeyed to Paris in order to demonstrate the fact before Alexander von Humboldt and Cuvier. Versalius in Stockholm had the experiment performed by Retziüs. Hardly a year later, Müller announced his discovery of the lymph hearts in amphibia; and also the results of his investigations on the coagulation of the blood.

Just and prompt recognition did not fail to follow in the train of these excellent results, and the consequent advancement and improvement in his material condition made possible for him other interesting journeys. In 1828 he visited Goethe. The spring of 1831 he spent in the Leiden Museum in Holland. In the autumn of 1831 we find him in Paris in the company of several of the great natural scientists, as Humboldt, Cuvier, Milne Edwards and others who were there at the time. One significant anecdote of this Paris trip should not be omitted. When for the first time Müller went to call upon Dumereil, the latter was very busy, and, since he did not know whom he had to meet, somewhat peevishly directed Müller to the door. Müller, however, as he was almost thrust out, pushed in his head and called out to Dumereil, "Yes, but the Coecilien in the young stages *do* have gill openings in their necks!" This thrust, it is needless to say, worked as a magic word to gain a long and pleasant interview between these two investigators.

In the year 1832 Rudolphi died at Berlin, thus leaving vacant the foremost position in anatomy and physiology in Germany. Negotiations were already in progress to secure as Rudolphi's successor Dr. Tiedermann from Heidelberg; but at this point in the proceedings Müller determined upon a unique step. He sent to his old friend and former benefactor, the Minister von Altenstein, copies of his works together with a letter in which he ("believing that the importance of the affair would furnish its own excuses") brought himself prominently into the proposition. He said, in part, that it was no more than right that the first and highest position of the kind in Germany should belong to the greatest among scholars; furthermore, that if this man were not Johann Friedrick Meckel, then he believed himself to be the foremost zoologist and physiologist in Germany.

This letter had results: the Minister von Altenstein at once ordered Müller's nomination; and on Easter, 1833, Müller, not yet thirty-three years old, entered upon his duties as "professor ordinary of anatomy, physiology and pathological anatomy, and director of the Anatomical Museums" in the University of Berlin.

The first fruit of Müller's residence in Berlin was the completion of his "Handbook of Physiology," which he had begun long before he left Bonn. Appearing in three parts, it was at last completed in 1840. These volumes represented a piece of work unparalleled in the field of physiological literature. The only work which could be compared with it was Haller's "Elementa." Müller's labors in preparation for this work included an immeasurable number of single observations with reference to the physiology of the voice, of speech, of hearing, of nerve physiology, of teachings on the blood—all of these rest, to a very great extent, upon Müller's own discoveries. The "Handbook of Physiology" was accepted with almost universal accord as the most valuable treatise on general physiology that had appeared in the long interval since the time of Haller. It is perhaps of interest to observe that these two writers have much in common, for in both we perceive the fundamental desire of placing the doctrine of physiology upon a basis of fact. Anatomy, human and comparative, experiments on animals, chemistry and physiological science in its various departments, are all called in to bear upon the investigation of the truths of physiology. As one of his commentators has remarked, Müller in this work, as in his others, takes nothing on trust; every statement, whether matter of fact or of doctrine, is thoroughly tested; difficulties, however perplexing, are never evaded or slurred over; defects, however much they may deface the picture to be presented, are never disguised. The result of each quest, whether success or failure, is honestly told and there is no yielding to the temptation, so powerful with writers of systems, "to round off a ragged subject with smooth plausibilities." The influence of the "Handbook" was immense, and the judgment of it appears to have been conditioned not alone by the physiological data it contained, but also by the collected facts of importance to the medical profession.

With the completion of the "Handbook," Müller's activity in this particular line of work seems to have practically ended. From this time on he engaged himself to a greater extent in the fields of comparative anatomy and zoology; and in these subjects, as also in his physiology, Müller excelled both in the abundance of his observations and in the wide range of his discoveries. In his work on the comparative anatomy of the myxinoid fishes, Müller lays down the morphological plan of the vertebrates in their simplest form. The title conveys but a faint notion of the scope of this work. Although it treats chiefly of the anatomy of this particular family of fishes, it is rich in new and original matter in which the structure is compared with that of other families of fishes, and the facts sagaciously applied to the elucidation of greater questions in animal morphology. Regarding Müller's study of the Echinoderms, we may quote from an address by the president of the Royal Society of London:

> Professor Müller early applied himself to the study of the structure and economy of the Echinoderms. After describing in a special memoir the anatomy of Pentacrinus, so interesting as a living representative of the extinct Crinoidea, and publishing, in conjunction with M. Troschel, a systematic arrangement and description of the Asteridea, he was at length happily led to investigate the embryo life of this remarkable class of animals. The field of inquiry upon which he entered had scarcely been trenched upon before, and he has since made it almost wholly his own by persevering researches carried on at the proper seasons of the last nine years, on the shores of the North Sea, Mediterranean and Adriatic. In this way he investigated the larval conditions of four out of the five orders of true Echinoderms, and has successfully sought out and determined the commonplace followed in their development, amidst

remarkable and unlooked-for deviations in the larval organization and habits of genera even of the same order. His inquiries respecting these animals have made us acquainted with the larval forms, with relations between the larva and future being; and with modes of existence, such as nature has not yet been found to present in any other part of the animal kingdom. Finally with the light thus derived from the study of their development, Professor Müller has subjected the organization of the entire class of Echinoderms, both recent and fossil, to a thorough revision, and has added much that was new, as well as cleared up much that was obscure in regard to their economy, structure and homologies. It is to their researches, which occupy seven memoirs of the Royal Academy of Sciences of Berlin, that more special reference is made in the award of the medal.

It was not long after his arrival at Berlin that Müller established the *Archiv für Anatomie und Physiologie.* Of this he continued the publication until the time of his death. This journal, during the period of its existence, formed a principal medium of publicity for the labors of the leading physiologists of Germany; and the establishment and continued superintendence of it by Müller, in the midst of other laborious employments, must be regarded as an important service rendered to science.

About this time, independent of Müller, his pupil Schwann, following apparently in the footsteps of Schleiden, made the discovery that the animal organism, just as the plant organism, was composed of elementary cells. Müller appears to have been the first to recognize the great significance of this discovery. He immediately employed the new fact for the explanation of certain disease phenomena and clearly pointed out the agreement between tumors and pathological and embryological development. His excellent work on the finer structure of morbid tumors signifies the beginning of all microscopical investigation in pathological anatomy, and here we see the fountain-head of that stimulus which, brought to bear upon the young investigator Virchow, gave rise to that well-known and comprehensive work on "Cellular Pathology."

Concerning the other events of Müller's life, during the Berlin period, it takes little time to relate. The routine work in the Berlin Anatomical Museum was interrupted only by the scientific expeditions which the desired investigation of the sea fauna afforded. The East and North Sea, Sweden, Norway, the coast of the Adriatic and Mediterranean, from Triest to Messina and Marseilles, formed the territory of Müller's scientific explorations. On one of these trips, in 1855, Müller experienced a serious danger. He was returning with two pupils from a journey to the coast of Norway, when at night the steamer *Norge* on which he sailed was rammed by another and speedily sank. Nearly fifty people lost their lives; and among them one of Müller's young companions. In a letter to a friend in England, in which Müller gives an account of the disaster, he says that upon finding himself in the water at first he kept himself up by swimming. But having his clothes on, he soon became exhausted and would have perished had he not caught hold of a ship's ladder which was floating by. For a long time he held on, and had nearly given up all hope of assistance when he was picked up by a boat from the other vessel. His remaining companion, Dr. Schneider, saved himself in a similar way. This event seems to have had a deep effect upon Müller, and although he still resorted to the seaside, ever afterwards he dreaded to trust himself on shipboard.

When, for a second time, Müller was chosen director of the Berlin Museum, it was certainly most unfortunate that his directorship fell in that memorable year of the revolution, 1848. Although Müller felt himself to be truly German, he was apparently no more of a politician than Goethe. He could experience no sympathy for the democratic rashness which on all sides of him was now being manifested. It was a time of civil commotion when political agitation distracted the whole academic being, and both students and professors were deserting the laboratory and lecture room to equip themselves as soldiers of the revolution. Müller, whose quick spirit had led him, in the olden days of the Student Alliance, to take so active a part in the threatened political eruption, had become a sober conservative. His situation was now one of difficulty, and not without peril. He strove manfully to maintain authority, and even those who took a different view of passing events paid willing tribute to his honesty of purpose and to the personal courage he displayed in the most trying circumstances when the university buildings had become the center of the intense revolutionary movement. Müller naturally feared the destruction of the priceless treasures of his collection. Regarding the state of his mind we can obtain some conception from the words of his distinguished scholar, Rudolph Virchow, who upon Müller's own request became his follower as professor of anatomy and physiology at Berlin University. Regarding these days of the revolution, Virchow has written as follows:

> He trembled for the safety of the university, for whose treasures he felt himself to be personally responsible. Day and night he remained at the museum, ever on guard. He tore down agitating placards. He ventured with personal danger among the students. On the day of the great citizens' parade, with his own hand he seized away the black banner which was stretched across the balcony of the university building. But the movement more and more escaped the authority of the academic jurisdiction. In the teaching body of the university grew the voicing of disharmony. The professors and the private lecturers made diligent efforts to be heard and some of them (appointed as a committee, to which I also belonged) argued the matter with the director and the senate in a very unpleasant conversation.

Thus it is apparent that Müller was asked in the most kindly spirit to give up, at least temporarily, the position as director; for Virchow continues:

> Thus all agreed, in order to relieve the at least exposed position of the director, to a painful duty; and it was an actual deliverance when, at the closing of the university year, he could give into other hands the office which he had taken upon himself.

This was, perhaps, the most unfortunate directorship since the founding of the university; for the man who possessed the least political inclination was called upon to display, in that time of agitation, the abilities of the politician and statesman.

From this time on Müller worked as hard as ever, but with sadly altered spirits. The nervous strain of overwork was beginning to tell. He suffered much from sleeplessness and this condition he fought with larger doses of opium, which in turn led to a more serious trouble of the heart. In the winter of 1856–7 his health received the first open shock when a gastric fever, the first serious illness since 1827, necessitated the giving up of his lectures. In these days he worried much about himself, feared typhoid fever and wrote to his son, Max Müller, at Cologne. He set in order all his private affairs and engaged, in the case of his death, Dr. Diffenbach to open his body. At this time, however, he developed only a slight trouble in the joint of one foot, and the next summer found him again in fair health. The following winter, however, he again overburdened himself with work, suffered even more than ever from lack of sleep, and again resorted to large doses of alkaloids. For some time he had suffered from moments of dizziness, but had become accustomed to attribute them to the long hours he spent bending over his microscope. These attacks now became so frequent that he dared not venture even on his library ladder. In the evening one would see him sitting listless in his easy chair; or, as if driven by a deep inner anxiety, and gloomy foreboding, pacing restlessly at night through the secluded streets of Berlin.

Easter of the year 1858 did not bring him the accustomed feeling of satisfaction at having completed a period of uninterrupted scientific work. At the end of the summer semester he fully realized, but all too late, the necessity of taking the most energetic measures to bring about an improvement in the condition of his health. He again called his son from Cologne, and, after a consultation, decided to give up all his work and lectures in physiology. He planned an early consultation with his physician in order to decide more definitely regarding his future work; but the end came suddenly. On the morning of the day when this consultation was to have taken place, Müller was found in his bed, lifeless, April 28, 1858. It is needless to say that the tidings of the sudden end of his laborious and valuable life caused profound sorrow in every part of the world where science is cultivated.

II

Having now considered the more prominent events of Müller's life and his career as a man among men, let us now consider more in detail the nature of Müller's work, its fullness and its limitations. Let us attempt to discover wherein it has proved so substantial a foundation for the later development of modern physiology; and lastly let us make ourselves better acquainted with Müller's strong personality, as it was manifested in the home and among the ranks of his students and associates.

In the estimation of a man's prominence it is hardly necessary to remark that the importance which he may assume is always a relative quantity. It is first roughly drawn from a direct comparison of this individual with other individual workers. It is then tempered, as we may say, by a consideration of the relation of the individual activities to the whole field of knowledge existent at that time. There may be great physiologists, great morphologists and great systematists, but the criterion invariably to be used to determine the highest rank must ever be that comprehensive vision which, as Verworn remarks, is able to grasp in a single *Weltanschauung,* the whole breadth and depth of natural scientific inquiry—that comprehensive analytic and synthetic quality of mind which brings isolated unities of fact into concrete principles. It is from this point of view, and by these standards that we must judge the extent and quality of the work of Johannes Müller: first examine into the relation of his activities to the field of natural science of his day; and, secondly, ascertain the relative value of his work when compared with the labors of other men whom posterity has been accustomed to hold as leaders in the rank and file of natural scientists. And yet, before we can fully understand—much less appreciate—the intrinsic worth of any phase of Müller's many-sided activity, we must first take time to examine briefly the condition of the biological science just previous to the period of Müller's greatest work.

We have already in the course of our discussion made mention of the scope and value of Haller's work in physiology; yet we may be pardoned, perhaps, if, in the present connection, we again make reference to some of the more important characteristics of his period, which extended from 1708 to 1777, and closed something over half a century before Müller's began.

As Galen, in the second century, had shown his recognition of the practical value of physiological data and had laid as a basis of medicine, the practical knowledge of vital phenomena; as Harvey, by his brilliant discovery of the circulation of the blood, temporarily revived, after a sleep of thirteen centuries, the exact experimental method in physiology; and after many other investigators had made important, though isolated, contributions to the budget of physiology, we find Haller bringing together the extensive mass of facts and theories and establishing thereby physiology as an independent science which should pursue not only practical lines for the aid to medicine, but also undertake theoretical aims for their own merit. We find many theories and speculations in the air during the period from 1750 to 1830, the latter date marking the beginning of the period of Müller's greatest activity. As a result of the microscopical observations made in last part of the seventeenth century on the development of the ovum, the theory of preformation was attracting wide interest. This had stimulated Caspar Friedrick Wolff to the production of his *Theoria Generationis,* which was unfortunately held in the dark by the opposition of Haller who could not accept the principles which led, at a somewhat later date, to the conception of Epigenesis. The theory of irritability was also a bone of contention, and though it was materially furthered toward the true conception by Haller's own researches, these last, unfortunately, served also to further a doctrine which thoroughly permeated and confused the development of all physiology down to the middle of the nineteenth century. This was due chiefly to the following fact: That the seeming impossibility of explaining the phenomena of irritability led to the welcoming of the theory of vitalism, or vital force, which asserted a distinct dualism between living and lifeless nature. The vitalists at this time (and nearly all the natural scientists, except perhaps Rudolphi at Berlin, were vitalists in a greater or lesser degree) were discarding the mechanical and chemical explanation of life phenomena, and were introducing such mysterious and inscrutable explanatory principles as *la force hypermécanique* and the *nisus formativus.* In this acute and exhaustive manner were explained even the most complex of vital phenomena.

Toward the end of the eighteenth century, however, some twenty years before the birth of Müller, a new note was being sounded from the ranks of German scientists, especially from Reil, whom we may well call the censor of German vitalism. In his work "Ueber die Seelenskraft," he was forcing upon unwilling hearers not only the conception that the life phenomena of living organisms are regulated by chemico-physical laws, but that there were higher principles in control which were present only in living matter. The few adherents to the chemico-physical hypothesis were, during the last years of the eighteenth century, receiving fundamental support from such men as Ritter, Galvani and Humboldt. Through the work of these men the notion was becoming popular that the galvanic current was the cause of all vital phenomena.

Among the chemical and physical discoveries of this time we can mention the advance of vegetable physiology through Ingenhaus (1730–99), who developed the theory of the consumption of carbon dioxide by plants; the discovery of oxygen by Priestley (1733–1804) and Lavoisier (1743–94), and the further discovery in this line by Girtanner, who showed that the venous blood is aerated in the lungs. Thus the existence of the mystical "pneuma," which had clung with a peculiar persistence to centuries of physiological thought, had now become a reality. The anatomical researches of this period were characterized by one discovery in particular, announced by Charles Bell in 1810; that is, the fundamental law of specific nerve physiology, to be later experimentally proved by Johannes Müller. In microscopy, Spallanzani, Treviranus and others were dealing what we may call only the first of a long series of death blows to the hydra-headed theory of spontaneous generation, which was not eventually disposed of until the excellent work of Pasteur, over half a century later, and even now is often found lingering in popular scientific lore.

A consideration of these foregoing facts demonstrates to us that the greater number of these exact researches had been carried on in France and England. When now we turn with special interest to Germany, we find that her scientific thought had been fermenting in that powerful intellectual narcotic, the *Naturphilosophie,* which, under the great influence of Hegel at Heidelberg and Berlin, was stupefying every branch of accurate scientific research throughout Germany. Of the tendency of this movement to avoid the deductive method of research and to build up a conception of nature upon theoretical and speculative conclusions, we shall speak further. For the present, however, having gained some understanding of the condition of natural science, especially physiology, previous to the period of Müller's greatest activity, let us now consider more in detail Müller's relation to these movements, philosophical and otherwise.

Müller, as nearly every other investigator of his time, was a vitalist; but, as Verworn has said, "Müller's vitalism had an acceptable form." Although to him vital force was different from the forces of lifeless nature, its administration nevertheless followed certain physico-chemical laws. In this, Müller's conception seems to be modeled after the idea of Reil, the leader, as we have said, of the most rational form of the doctrine of vitalism in Germany. Müller maintained his position as a vitalist to the very end. He cherished to the last the thought of the existence of a "life energy." We well know how the activity of his pupils has apparently disproved forever this conception for natural science; and how it has led to the opposite extreme, the rather one-sided materialism of the present day.

When we turn to consider Müller's relation to the *Naturphilosophie,* we recall how he contracted this spirit while he was at Bonn, and how he was rescued, at least from its extreme influences, by Rudolphi at Berlin. Throughout his Berlin period, Müller devoted much of his thought to freeing natural science from the influence of the *Naturphilosophie.* The result was that not long after the death of Hegel, in 1831, the dangerous play with mystical words became gradually eliminated from the consideration of life phenomena. From this time on, the problems of living substance were furthered, especially by Müller, with the implements of comparative anatomy, of physics and of chemistry. In bringing about this condition, and in establishing the deductive scientific method as alone admissible in the realm of natural science, we must look upon Müller as a reformer whose work has been of enduring benefit to science. The nature of his vitalistic hypothesis did not prevent him in the least from directing his labor to establish life phenomena on a physico-chemical basis. Even the vitalistic principle, as it appertains to the philosophy of the present day, is largely a matter of man's personal and ultimate view of his own life and his own destiny.

In our consideration of the relation of Müller's thought to the *Naturphilosophie* of his time, we must not deny the fact that Müller did recognize a grain of truth in the general philosophic tendencies of that day. As Verworn says: "While keeping constantly in mind the large problems and the goal of science, he regarded critically the special methods and questions only as means to an end—as means for arriving at a harmonious conception of nature." Throughout his whole life he remained steadfastly true to this philosophical conception of science which he had set forth in his inaugural address, "Concerning the Need of Physiology for a Philosophic Consideration of Nature." Verworn further laments that modern science has now so largely lost this element of philosophy, which it had gained as a result of Müller's treatment.

Having dealt thus far with the more abstract phase of Müller's activity and thought, let us now consider more concretely, for a few moments, first the extent of the realm over which Müller exercised so marvelous a command.

When we examine the list of 260 and more complete publications which have come from Müller's pen, we are better able to comprehend the universality of his activities; and it must be understood in this connection that in this great number there are few which represent merely a superficial dalliance with a possible line of investigation. They demonstrate, in almost every case, that Müller plunged boldly into the very heart of the matter which at the time received his fullest consideration. The main subjects to which his contributions appertain, include the following:

1. The Physiology of Motion.
2. The Life of the Fœtus,
3. The Sense Organs.
4. Dissection of Invertebrates; also
    (*a*) their development,
    (*b*) the histology of their tissues.
5. Nerve Physiology.
6. Animal Chemistry.
7. Human Anatomy.
8. Ethnography.
9. Comparative Anatomy of Vertebrates.
10. Physiology of the Voice and Speech.
11. Pathological Anatomy.
12. Systematic Zoology.
13. Paleontology.

It is clear that such an extent and variety of undertakings could not result from a single line of investigation, but required a universal activity which it is safe to say has never been equaled by any investigator since Müller's time. A better conception of the degree of this extraordinary activity may be gained when one considers that Müller, from 1821 (when he was nineteen years old) to the time of his death, thirty-seven years later, produced, year in and year out, an average of one scientific article of from three to five pages, and with from one to three plates, every three weeks. And in none of these do we find the spirit of his work dictated by the desire to show that he could get some sort of a result out of this or that kind of investigation; but rather by the burning desire to survey and to understand the interrelation of all life phenomena.

It would seem that an unconquered field of knowledge left him no rest, and was for him a stimulus to activity just as much as was the knowledge of the existence of an unconquered people to Alexander the Great. At the first opportunity his attention would be directed to it, and never would the field be abandoned until its truths and its principles were at last incorporated in Müller's own system. This, for Müller, meant no simple undertaking. It included the universal proof, the definite transformation, the deepening, the enriching, the building up and the ordering of every detail of the work; so that from each such acquisition the greatest value to science invariably resulted.

This capability of Müller's is shown especially well in his work on the Echinoderms. He early applied himself to the study of the structure and habits of a single group of this interesting branch of animals. From this study he was led to consider the embryonic development, and, finally, having pursued his investigations in this line into four of the five orders of true Echinoderms, he culminated this great work by subjecting the organization of the entire class of Echinoderms, both recent and fossil, to a thorough revision. In this same thorough and exhausting manner, Müller attacked all possible points in the illimitable field of anatomical and physiological knowledge; and the insight into nature, gained through his own exhaustive researches, yielded to him a sureness of judgment which seldom failed him in the decisive moments of his career. An accurate personal knowledge lay at the bottom of his every work.

In the period of his greatest activity, when he was working simultaneously upon "The Development of the Reproductive Organs," "The Development of the Glands," and also the first volume of his "Handbook of Physiology," together with papers on "Osteology" and "The Myology of the Myxinoid Fishes," he must have possessed the ability to profitably divide his interest and to oscillate with a remarkable ease between these several objects of thought and investigation. The result is perhaps still more marvelous when we realize that, as a rule, Müller went over the same line of investigation three times: the second time while he was writing his results, and the third time when the article was in the hands of the printer. Müller's manuscripts are said to have been the "terror" of all typesetters.

There was one peculiarity of this man of genius which, though perhaps a fault, no doubt favored the high degree of productiveness which Müller manifested throughout his life. This was his indifference to the formal completion of his written works. At the culmination of a certain line of investigation, in which he had arrived at definite, and usually important, results, he found too attractive the conclusions and speculations dependent upon these results, to spend his precious moments preparing or finishing his manuscript for the general reader.

Although Müller took, in the earlier part of his life, a certain interest in art, literature and music, it was usually the practical alone which was of consequence to him; and if this phase of the subject were once assured, he went forward in his work without much regard for the polishing or the agreeable rounding-off of his subject. And yet, had Müller lived under different influences and if he had dedicated to the superficial side of his work the same carefulness, we are bound to say that, like Cuvier, he too would have been a master of scientific style. But in spite of this tendency, in what Müller did write he was usually most thoughtful of the manner of his expression. He would sometimes read to members of his department, without disclosing the object, descriptions of certain forms to see whether or not he could awaken in his hearers the conception which it was his desire to implant. He was accustomed to enhance the value of his descriptions by forceful comparisons wherein the wealth of his imagination is readily recognizable. The dredging apparatus which worked before his laboratory window, the hood-like cap of Frau Martha, the little dagger of Cornelius, the sketch of Faust—all these common objects of his sight while hanging on the walls of his study were employed, as much else, for the elucidating of certain phases of the problems which occupied him at the time.

When we come to consider the nature and actual value of Müller's scientific work, it appears that in general he has more developed the principles set in motion by others, than himself given to the world epoch-making discoveries. In his teachings of the glands, of the voice, of the sense of sight and of the tumors, he has, with a tremendous power of work, heaped up an amount of raw material which not only became united in his own system, but has furnished a basis for much of the work in physiology since his time. It was Müller who first clearly recognized the interrelation of psychology and physiology. We remember that in his doctor's thesis he defended the position: "Psychology is nothing without physiology." In this regard Müller's own investigations, wherein he formulated his doctrine of the specific energy of the sense organs, demonstrated how fully dependent psychology might be upon physiology—a conception which in more recent times has been developed so far as to arouse in many the belief that psychology should be taught as but a branch of physiology. That Müller saw so clearly the interrelation of these two branches of knowledge is decidedly a point in his favor. His theories were upheld, moreover, by the many facts presented in his works, "Concerning the Comparative Physiology of the Sense of Sight in Man and the Lower Animals," "Regarding the Phantasmal Phenomena of Vision," also "Concerning the Life of the Soul"; and many other references in his "Handbook of Physiology."

Another, and perhaps the greatest, debt which the world of science to-day owes to Müller is for his establishment of physiology upon a comparative basis. This conception did not first arise in Müller, however, but was previously expressed by his teacher, Rudolphi, who had already emphasized the motto: Comparative anatomy is the surest support of physiology. Grasping the fuller significance of this thought, Müller worked throughout his life to uphold the view that physiology can be only comparative; and among the vast number of his physiological works, there are few in which this comparative principle is not more or less clearly expressed.

A further consideration of the nature of Müller's work shows to us the evident necessity of making one concession; and yet one which, under careful examination, may not, after all, detract from the fame which the world accords to him. This is the fact that in spite of his varied activities Müller was never able to make what we may call a scientific discovery of the first rank. We can find issuing from his hand no single observation which, as has often been the case with other so-called great natural scientists, carries down with it through the ages the name of the fortunate discoverer. With the names of Priestley and Lavoisier will ever be linked the discovery of oxygen. The mention of the name Harvey immediately brings to mind the thought of the circulation of the blood, as with the name of Newton we invariably associate the statements of the laws of gravity. But discoveries of equal or even lesser importance can never distinguish the name of Johannes Müller. Even his excellent work on reflex action and the function of the anterior and posterior spinal nerve roots —these do not belong to him alone, for Charles Bell some years before had already promulgated the theoretical law; yet it remained for Müller to prove this law, and by nice experimentation to establish its universal application as a fact. Schwann presented to the world of science that noteworthy discovery that the animal tissue, just as plant organization, is composed of elemental cells; but it remained for Müller to show the highest importance attaching to this discovery, and to lay down the law of the correspondence between embryonic and pathological development.

This failure of Müller's to make a discovery of the first order can not, with justice, however, be made to count against him. As DuBois Reymond has said, "The most important discoveries can, and often do, play into the hands of insignificant investigators." "That Müller has no such discovery to his credit," continues DuBois Reymond, "can be called as little a failure as that a merchant, who becomes rich through industry and perseverance, should never have been visited by a great fortune." If, in the time when his productive strength stood at its maximum, instead of loosing his great power against a group of widely-extended activities, Müller had undertaken a course in a single definite direction, according to the view of Schiller, that strong stimulus would have been lost to the development of physiology.

Like Müller, Haller also, though he manifested an all-comprehensive knowledge of the field of physiology, failed in yielding an epoch-making discovery. Between these two men, as we have already noted, many points of similarity exist. But, notwithstanding the immense value which Haller rendered to science by his collection and ordering of the tag-ends of physiology up to his time (1775), his work as a whole is excelled by that of Müller with his over-weighing power of judgment and the massive comprehension which took in the whole realm of biological science. While Haller rendered an immense service by uniting the facts of physiology into a certain order and system, Müller took that system as he found it, worked it over, did away with every vestige of the false *Naturphilosophie,* deepened by his own exhaustive researches every channel of it, and turned into those channels the fresh spirit of a new physiology of comparative anatomy.

We come now, in closing, to a consideration of Müller's personality. From his father Müller inherited the strong and active body characteristic of the Müller line, which is traceable far back into German history. We can picture him a man of medium height; in his youth somewhat slim and of an elegant appearance; the breadth of his shoulders in good keeping with the well-shaped head, which was always held erect with a certain attitude of determination. Lithographs and photographs, pencil, pen and brush drawings presenting Müller's appearance at different times in life, have been given to the world; but, as one of his biographers has said, no picture could accurately repeat, now the sad, now the illuminating, splendor of that dusky countenance, with the dark locks of hair and brilliantly glowing eyes.

While we know that Müller received his physical characteristics from his father, it was from his mother that he appears to have inherited his mental qualities. Among these we may distinguish chiefly the strongly-developed sense of order and method, and the deep spirit of enterprise and of indefatigable activity. To these were added a thorough knowledge of men, a great gift of observation, a conscientious punctuality, and a firmness of purpose together with a knowledge of the appropriate both in speech and in action. In his domestic life Müller appears to have been a true husband and to his son and daughters a good father. His home life was of the pleasantest —at least until the misfortune of ill-health in his later life.

As Müller's work as a whole is most comparable to Haller's, so we can say that his personality must have had much in common with that of Pasteur. In both we see the fine sensitiveness of mind, the same modesty in self-assertion, the same love of simplicity, the tenacity of purpose, the scrupulousness for details and the same religious devotion to the hardest labor: these attributes make up a character not altogether common in the general biography of the older school of natural scientists.

Müller's address was characterized by that stiff formality peculiar to the old school type of German professor; and yet with this he combined the dexterity and activity of the more modern scholar. His conversation was never productive. The constant consideration of the various problems of his activity was usually uppermost in his mind and, although he would talk pleasantly and interestingly of many varied subjects, as art, architecture and music, it was to some phase of his labors that the further discussion of these subjects almost invariably led back. And yet, in the circle of his own family, in a group of personal friends, or on his vacation and outings with his nets and microscopes, he could be the most congenial fellow, entering with enthusiasm into whatever duty, sport or pastime presented. Recreation for its own sake, however, Müller seems never to have desired. Yet in his earlier years at Berlin, he was seldom seen exhausted. In his later life, however, the intense nervous strain under which he worked was a source of much regret to his many friends; and the knowledge of his frequent use of opium and other alkaloids to bring him sleep a deeper source of sorrow to those who knew and loved him best.

As a teacher in the anatomical theater and in the class room, as also a guide of young investigators in the laboratory, Müller possessed an extraordinary ability. And yet, in the beginning he had no natural gift of speaking, no eloquence and no talent for foreign languages. Indeed, his early years as academic lecturer at the University of Bonn were, in this particular respect, not in the least promising. With constant practise, however, he was later able to develop a clearness in speaking, and a straightforwardness of expression, which, in itself, approximated to the gifts of eloquence, so that at Berlin he was considered one of the best of university lecturers. His delivery was never of the demonstrative sort, which held an audience spellbound by its bubbling vivacity, its ravishing fire of words, or through a kaleidoscopic blending of current witticism with scientific truth. He never went rambling in a lecture, either in thought or in person. His delivery was usually cold and calculating; and yet in some moments he could arouse, through his own deep earnestness, the highest enthusiasm among his students for the subject whereof he spoke—an enthusiasm, the fruits of which have been well shown by the works of the many students, afterwards famous, who received their first impetus from contact with Müller during his periods at Bonn and at Berlin.

In this regard, it is almost needless to say that Müller's position in Berlin resulted in a powerful influence over the younger natural scientists, especially in the northern part of Germany. His personality, as we have seen it, was one to attract students and to hold them when once they knew him well. He planned for them, and often accompanied them on many student trips throughout Germany and even into Norway and Sweden for the purpose of extending various phases of their biological study. In spite of his apparent coldness and constraint, he was, as DuBois Reymond has said, always a ready "comerade," and his views, his books, his apparatus of all kinds, were ever willingly shared with all who desired them.

To the same degree in which Müller was independent in his thought and work, he desired this quality in his students. In his relations with them, notwithstanding his thorough friendliness, it appears that in the laboratories Müller would seldom enter into an ordinary conversation. Regarding this point, DuBois Reymond says in his "*Gedächtnissrede,*" "The greatest reward for us students was when Müller relaxed and spoke in common conversation along the lines of highest pleasantry." Even before his fame as a leader in the field of natural science had gone abroad, and while dependent upon his worth as a teacher alone, he had constantly at his side a circle of eager students who clung to him with enthusiasm. Gathered about him in the earlier days at the University of Bonn, before he went to Berlin, one finds such men as Claparède, Haeckel, Lachmann, Lieberkuhn, Anton Schneider and Max Schultze. Upon his departure to Berlin in 1833, many of his students of the Bonn period followed him, and one need only mention the names of Haeckel, Ludwig, Bischoff, Schultze, Volkmann, Brücke, Helmholtz, Virchow and DuBois Reymond, to indicate the immeasurable significance which, as a teacher and leader of the young investigators of that time, Müller must have exercised. The lines of work which he established, his disciples and followers have carried out, and to what extent, we all realize—not as royal inheritors of that vast sovereign power of their master, but, we may say, as governors over the smaller territories into which, like the empire of Alexander, the field of natural science became divided after the death of its last great ruler. Of this famous group of students, now Haeckel alone remains, DuBois Reymond having died in 1896. Yet all these men, at some period of their lives, have rendered grateful testimony to that common source of their first stimulus and earliest enthusiasm, Johannes Müller.

Look as we will through the history of natural science, we do not find an instance where a single individual, gathering about himself a body of select disciples, has by the infusion of his spirit of work sent abroad influences that have ruled so large a part of the territory of natural science. No such influence emanated from Haller, busily engaged in his collections and accumulation of the facts and theories of a century of physiological activity. Nor could it come from Cuvier, excluding from his circle of labor, as he did, the whole field of physiology and embryology, and preoccupied with his foibles of nobility. Nor was such influence from Darwin, secreted in the recesses of his study, modestly content to think, but not to speak. Nor from the combative Huxley, ever at the cannon's mouth with his evolutionary arguments. Nor yet from our more familiar Agassiz, with his noble retinue of followers, and a leader in our own popular thought of natural history though he was. These men have, it is true, been pillars in the development of the biological structure of the present time; yet their fields of labor have been most limited. But it was the nature of the case that it must be so, for no human individual, coming after Müller, could have the same grasp on the ever-extending realm of biological knowledge. Since his time there are few who have become masters of even a single territory.

In these days, when the scientific spirit is throwing its ever-increasing impetus into all lines of human activity, man has little opportunity to look back "to the mountains whence cometh his strength." The source of his to-day's blessings is either wholly overlooked, or, upon special occasions and anniversaries, is (with that feeling which Macaulay has called the "furor biographicus") made to glow in the colors of the sunset. Having avoided, as it is hoped, both of these extremes, we may quickly summarize what, for Johannes Müller, must ever stand as the criterion of greatness: With an all-including glance he was a master of the whole realm of natural science, which he widened until it became too great for its own government. With the certain power of genius, he studied the field of physiology, cleared away the rubbish, breathed into the earth his own spirit, and, in the end, left in the hands of his followers the thrifty seedling of modern comparative physiology, nurtured in the soil of an exact natural scientific method for the investigation of all life phenomena.

THE GENESIS OF ORES IN THE LIGHT OF MODERN THEORY

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IT is well understood, but often forgotten, that all the constituents of ore deposits are found in some form in the earth's crust, contained in more or less abundance in the rocks, especially in the eruptive rocks; and that they have been in some way collected from their disseminated condition in these rocks, and concentrated in veins, beds or other deposits.

Analyses of fresh eruptive rocks have demonstrated the existence therein of all of the ingredients of our valuable ores and their compounds. Few of them occur native like gold, silver, copper and platinum; and often, because of their minute quantity and fine state of subdivision, it is not possible to determine the precise form in which they are present.

The presence of sulphur, arsenic, antimony and tellurium indicates that there may be many metallic combinations in the eruptive magmas similar to those formed at later periods, nearer the surface.

The average composition of the earth's crust has been approximately estimated as follows:[1]

	Per Cent.
Oxygen	47.13
Silicon	27.89
Aluminum	8.13
Iron	4.71
Calcium	3.53
Magnesium	2.64
Potassium	2.35
Sodium	2.68
Titanium	.32
Hydrogen	.17
Carbon	.13
Phosphorus	.09
Manganese	.07
Sulphur	.06
Barium	.04
Chromium	.01
Nickel	.01
Strontium	.01
Lithium	.01
Chlorine	.01
Fluorine	.01
Total	100.00

[1] F. W. Clarke, Bull. U. S. G. S., 148, p. 13; J. F. Kemp, *Econ. Geol.*, I., III., 210.

Copper, lead, zinc, tin, silver and gold, although metals of great importance to man, constitute so small a part that their percentages are expressed by four to eight decimals, that is, between hundred thousandths and billionths of a per cent.

In some eruptive rocks, however, the percentage is much higher, and has been determined to be in the thousandths of a per cent. in the case of copper, lead and zinc, and one tenth to one hundredth as much of silver and gold.

The amount of metallic content found to occur as a primary constituent in unaltered rock is thus seen to be far too small to constitute workable ores, and indeed is often so insignificant as to be determined with difficulty. You all know that several per cent. of iron, manganese, zinc, lead and copper are required to make an ore valuable, the percentage varying, of course, with the locality, complexity of the ore and other familiar factors.

It is therefore apparent that a process of natural concentration is essential for the production of ore deposits, bringing into limited space the material formerly disseminated through ten thousand or a hundred thousand times that extent of ground, or accomplishing the same result by the removal of the admingled rock impurities.

Wherever this concentration is brought about by assembling of solid particles under conditions that admit of freedom of movement, we have placer deposits as of gold and platinum, of tin, iron and chromium ores, and sometimes of precious stones, such as diamonds, sapphires, rubies, garnets and others.

The ores found in veins, in disseminations throughout the rocks and in irregular shaped deposits in soluble rocks can not have been collected in any such manner. Their mode of occurrence and relation to the enclosing rocks make it evident that they have been slowly deposited from solution. And the only solvent of general distribution is *water*, with its varying content of acids and alkalies under changing conditions as to temperature and pressure.

Water is the magic instrument by which all the copper in Butte's vast mines, all the gold and silver of the Comstock and of Goldfield, were assembled; more potent than the Philosopher's Stone, more universal than the air we breathe; constantly at work, dissolving, transporting and redepositing. With indefatigable zeal and never-flagging industry it searches through the innermost recesses and penetrates the most closely locked chambers of the rocks, removing treasures through their very walls, and often repairing breaches made in the attack so skilfully as to defy detection, or to make the masonry stronger than when first laid. Small wonder that the ancients regarded it as one of the four prime elements!

But, although for several years water has been recognized as the great agent in the formation of ore deposits, geologists are not agreed as to the source of this water, the conditions under which it is most effective, nor the relative importance of its work in ascending and descending movements.

Regarding its source, we have those who believe with John Woodward, Franz Posepny and C. R. Van Hise that the water in the uppermost layers or outer zone of the earth, including the waters on the surface and in the atmosphere, accomplish the formation of ore by means of a perpetual circulation. From the air it falls on the earth as rain; through crevices and fractures it enters the rocks by reason of its head or the weight of more water on top of it, and finds its way deeper and deeper to the very lowest point where the density of the rocks will permit it to penetrate. Down to this depth, which is theoretically not more than five or six miles, the temperature has been constantly increasing, and the water by reason of this higher temperature has been gaining strength as a solvent and picking up alkalies or acids that enable it to hold even the most difficultly soluble substances in solution. Finding no escape downward, and urged on by cooler and heavier waters above, these saturated solutions begin to move laterally and upward, expanding and becoming of lower specific gravity because of the forced deposition of dissolved material as they become supersaturated. Following the directions of least resistance, these metal carriers reach the surface as hot springs or geysers through fractures caused by earth movements. Gradually the walls of these fractures become coated with vein minerals and ores, until the waters stop flowing or the fracture is healed and a vein is formed.

Then there are those like Vogt, Spurr, Weed and Kemp, who maintain that the chief source of underground waters is the unconsolidated magma of molten lava within the earth. These authorities point to the immense volumes of steam emitted from volcanoes; they call attention to the conclusions of European scientists who have decided that many of the hot springs can not be derived from meteoric waters heated and returned to the surface; they remind us that there is so much watery vapor derived from lavas that possibly the oceans themselves were formed from volcanic emissions. They point out the ease with which such waters, thus derived and so heated, could gather metallic substances at great depths and bring them to the places where they are now found. They mention the fact that there is a very general association between the more important mining regions and eruptive rocks; and they raise several serious objections to the premises of the disciples of the meteoric water school.

On this particular point we shall not dwell further; it is quite probable that both theories contain elements of truth; and that ore deposits have been formed by both magmatic and meteoric reascending waters. It is even possible in some cases to determine by the character of the minerals the origin and nature of the causative solutions.

As to the relative importance of the work of ascending and descending waters there is also divergence of opinion. There are few who still doubt the agency of descending waters in the formation of the oxidized ores, such as carbonates, silicates and oxides of copper, lead and zinc and silver chloride, or in the superficial or shallow alteration of the sulphides, arsenides or antimonides. The iron ores of the Lake Superior region, for example, are generally believed to owe their concentration to descending solutions, in this respect differing from many of the Scandinavian iron ores, according to recent descriptions.

It is not, however, the oxidized or "dry" ores alone that are now believed to owe their formation in large part to the action of descending waters; but the base ores consisting of chemical combinations of the metals with sulphur, arsenic, antimony, tellurium and some rarer elements. It is only within the past decade that it has been considered possible that the sulphide minerals are produced by reaction between sulphate or carbonate solutions and undecomposed sulphides or other minerals found in veins. Laboratory experiments have, however, shown that the operation is not only possible, but easily accomplished and duplicated under normal conditions as to temperature and pressure.[2] This is a fact of great importance and wide significance, for it aids in the explanation of many formerly puzzling phenomena of mines and mining geology.

It has long been noticed by the students of ore deposits that by far the greater number of mines become exhausted at comparatively shallow depths; that veins, instead of continuing downward uniform in size and composition, like dikes of diabase and porphyry, become smaller and of lower value with depth, and often disappear altogether. It is noticed also that the shape of many ore deposits and the distribution and paragenesis of the minerals which they contain can often be better explained on the theory of descending than of ascending mineralizers. Moreover, it is apparent that there are changes constantly in progress in those portions of sulphide ore bodies lying nearest the surface of the ground. These changes consist in the oxidation of the sulphides and their solution as sulphates. These sulphate solutions percolate downward into the veins or rocks below along the most open channels; and thus, by degrees, the upper zone of the vein is robbed of most or all of its sulphide minerals, and only a gossan or iron cap remains.

The process of oxidizing and leaching out of the sulphides in the superficial zone of ore deposits tends, first of all, to disguise the nature

[2] H. V. Winchell, "The Synthesis of Chalcocite," *Bull. Geol. Soc. Am.*, Vol. XIV., pp. 269–276, 1903.

of the unaltered ore below. In many instances the ore discovered from the outcroppings is gold ore. And gold mills are often erected and operated for years upon such ore, without a suspicion arising that extensive bodies of copper or lead sulphides occur at greater depths. Such was indeed the history of Leadville, Colorado; of Bingham, Utah; of Ely, Nevada, and of Mount Morgan, Australia. The latter is one of the world's greatest gold mines; yet it is now producing copper from its lower levels; and developments have proved it to be a great copper mine. Immense low-grade deposits of copper ore are found below the gossan at Ely and at Bingham, although it is doubtful whether the most experienced geologist or keenest observer of mineralization phenomena would in either place have felt justified in predicting the existence of the wealth below.

In other localities the metal values have either all been removed, or else the primary sulphide ore was too poor in gold to leave oxidized ores of value. In such cases the discovery of the subterranean treasures is purely fortuitous. Butte may be considered the most conspicuous example of this class. The outcrops of its copper veins contain the merest traces of that metal; and there is seldom enough silver or gold in them to justify mining even under the low costs obtaining there to-day. The zone of oxidation is generally from one hundred to two hundred feet deep; and if it had not been for the presence of another system of veins carrying silver, veins of different age and origin, but closely associated geographically, this greatest of copper camps might not yet have been discovered. It was in the search for silver ore that copper ore was discovered here, and one can not help wondering how many more camps equal to Butte may be undiscovered and unsuspected where no outcropping silver or gold mines attract the prospector, and reward the efforts of the miner. Here is surely an important and unexplored field for the geologist. The study of oxidized vein phenomena may yield results thoroughly satisfactory from both material and scientific points of view.

Below the zone of oxidation the chemical reactions which take place between the descending acid solutions and the unoxidized ores result in the formation of more and richer sulphides, down at least to the level of the lower limit of free circulation, and as far as surface waters penetrate. And as erosion of the surface is continually bringing deeper and deeper sulphides within the reach of oxidizing and dissolving surface waters the operation is in constant progress, and these lower-lying ores become more and more enriched until in some cases are formed bonanzas of world renown, and almost inestimable value. It is a fact of much significance that such bonanzas are generally limited to depths where descending waters may have penetrated at one time or another. Indeed the very channels through which the enriching solutions came can often be detected; and peculiarities of shape and position observed which can be explained with difficulty on any other theory.

Practised miners often point to the richness of ore shoots near the junction or crossing of veins. Indeed such pockets and shoots are usually sought and frequently found where two veins come together. This fact alone may not signify the instrumentality of downward moving waters. But when in connection with it we discover that rich ore shoots are also frequently found at the intersection of veins by faults, and zones of movement so recent or of such shallow depth or limited extent that the faults themselves are not veins, and have not been mineralized except near the intersected veins, and when the ore shoots thus formed occur on that side of the fault plane where they could have been formed most naturally by descending waters, and are wanting entirely in the corresponding place on the other side, then, indeed, we recognize beyond a doubt the agency of meteoric waters in both situations.

It is often possible where sulphide ores have been deposited in soluble rocks to distinguish between the products of ascension and descension, and here too the latter are frequently of much the highest grade.

This theory of secondary enrichment which is so frequently referred to in recent mining literature; and is still so little understood, depends, of course, on the existence of a body of primary ore, probably formed by ascending solutions. If there are no ores to be oxidized the downward moving waters will have no metalliferous burden to deposit. But wherever the rocks contain disseminated ore, no matter how small the percentage, there is a possibility of the formation of richer ores through the action of surface waters. And where the primary mineralization was itself comparatively rich, even though not a minable product, there the downward-moving waters may the more readily bring about concentrations of high-grade bonanza ore.

Bearing in mind this conception of the meaning of "secondary enrichment," and admitting that it is frequently accomplished through the agency of descending meteoric waters, let us briefly consider the conditions under which they are most active and efficient:

It is a proposition requiring no argument that if by the aid of mineral bearing solutions the ores occurring in veins are to be enriched, these solutions must enter the veins. And if all the meteoric waters which fall upon the outcrop of a vein or upon rocks containing disseminated ore run off rapidly down the mountainside without remaining to oxidize, dissolve and penetrate the vein with their load of mineral, there can not be any enrichment caused thereby. Furthermore, if the work of the surface waters is chiefly destructive mechanically instead of chemically there will be little opportunity for the deposition of secondary concentrations of ores within the rocks. If, for example, the principal effect of the rains and snows is to erode and wash away the exposed portions of veins with all their contained ores, there will be a scattering and wasting instead of an assembling and storing. In other words, secondary enrichment by descending waters depends first of all upon *the ratio of oxidation to erosion.* Where erosion is more rapid than oxidation the unoxidized sulphides will be found in the rocks and veins at the surface of the ground, and in the sands rolling down the beds of torrential streams as in Alaska. While if oxidation precedes erosion the uppermost zone of a sulphide ore deposit will be oxidized and leached of its base minerals, as is the case here in Butte, and to varying extent over the larger portion of the temperate zones of the earth. Assuming that the conditions are such as to permit the entrance of surface waters, and that the ground-water level is at some depth, which depth naturally varies from year to year and age to age because of many common geological phenomena, the factors upon which depend the extent of secondary enrichment are: (1) Quantity of water, (2) time, (3) temperature, (4) the physical structure and solubility of the rock containing the primary ore, and of the ore itself.

It is manifest that a large supply of mineralizing solution will accomplish greater results than a small supply, provided it follows the course of the ore. For the metals in solution can hardly escape precipitation by reaction with the primary sulphides present, sooner or later, at some depth; and the oxidizing and dissolving effects will certainly increase with the amount of active oxygen-bearing moisture available. In regions of very little rainfall there may be partial oxidation to the depth of several hundred feet; and yet there may still remain particles of the primary sulphides upon the very surface of the rocks. Chemical activity is great; but the thirsty rocks quickly absorb that part of the water of rains and melting snows which is not evaporated, and the work of oxidation is not so complete as in regions more plentifully supplied with rain. On the other hand, there may be such heavy and constant downpourings of rain, even in tropical regions, that erosion is again the most active agent.

The second of our factors is *time;* a commodity of which the geologist is accustomed to make most liberal and even extravagant use in his arguments and theories. In this he is frequently justified; and the most astonishing results may be produced by the long continued but slow operation of natural forces in any given direction. Events of the past few years have, however, reminded us forcibly that catastrophic phenomena must not be forgotten in comprehensive reviews of the earth's history.

The time element enters in a variety of ways into the problem of ore formation by descending circulations. Thus an ore deposit formed in its primary, low grade constitution during earlier geological periods, such as the Cambrian or Huronian, and during all of the subsequent ages exposed to the action of superficial agencies unhampered by subsequent covering of later rocks, has a thousandfold the opportunity for concentration of its ores that is presented by similar rocks and ores formed during later geological epochs, say the Tertiary. This is exemplified by the iron ores of the Mesabi range as contrasted with the glauconitic deposits of New Jersey or Texas. During almost all the ages since the Cambrian the iron ore formation of the Mesabi has been exposed to the weather, covered only for a geological moment during a part of Cretaceous time. The result is the largest and purest deposits of iron ore ever discovered, while rocks of similar composition but much more recent formation exhibit only the initial stages of ore formation.

Another way in which time affects ore deposition is in connection with the rate at which the waters move in a vein. Solutions of a given composition may move so rapidly as to produce but little effect, or may move so slowly that they clog up or retard other active waters after their own power is exhausted. Upon a steep drainage slope or mountain the waters may pass off so rapidly, even below the actual top of the ground, as to exert but little influence, or they may move with just sufficient rapidity to accomplish their maximum of chemical effect.

Our third factor, *temperature,* is of great importance. In the first place, oxidation, which is but another name for combustion, is greatly accelerated or retarded by slight changes in temperature. Sulphides which remain immersed for centuries in water under a glacier in Alaska would be completely oxidized in a few years exposed to the heat of the sun on a southern slope in Colorado or California. In the next place, the rate of solution depends directly upon temperature, increasing as the temperature rises, and, itself a process of heat consumption, is greatly facilitated by heat from external sources. Thus in warm rocks, in mild climates, upon the sunny side of mountains, there will be the most favorable conditions as regards temperature, for the formation of secondarily enriched ore deposits. The experienced prospector will tell you that it is in precisely these localities that they are found, although he never before heard any explanation for it.

Lastly, the physical structure and solubility of the rocks and ores affect their susceptibility to later enrichment for perfectly obvious reasons. A dense rock is not readily entered by mineralizing solutions. Likewise an insoluble one is not easily replaced and does not afford lodgment for ores. And if the ores themselves are not readily attacked by oxidation or by solvents, the quantity, time and temperature may all be sufficient to accomplish great results with more tractable ores, but have practically no effect upon these refractory ones. A good example of this again is found on the Mesabi range where the heat of an eruptive rock has so altered a portion of the iron formation for many miles that it has resisted surface solution and concentration, and is a worthless low-grade mixture of rock and magnetic ore still; while away from the influence of the eruptive, have been formed the iron ore deposits which have given to the iron and steel industry of this country the raw material required to make us preeminent in the markets of the world.

Reduced to more simple language and ideas the foregoing remarks amount to a statement that climate, sun, rain, average temperature, topography, depth of soil or surface débris, erosion, glaciation and other common and often unobserved influences and conditions have decided bearing upon the important question of ore formation.

These are the phases of our modern theory that have received little attention hitherto; and are yet of practical value that can hardly be overestimated. We find few bonanzas of high-grade ore in Siberia, Russia, Alaska, British Columbia, Washington or northern Ontario. Our theory tells us why they are not to be expected, and why such enriched ores as are found seldom extend downward to great depths. We turn to regions of milder climate, less glaciation, gentler topography, and we find the rocks altered and softened and oxidized to some depth below the surface. We find that the veins wear "iron hats"; and beneath them we find bonanzas reaching to great depths. We find our best ore shoots on the sunny sides of the mountains, while the veins on the northern shaded sides where the snow lies till mid-summer and the rocks are cold produce no such rich ore. We begin to realize that our theory is based on fact and proved by observation; and that it justifies us in placing confidence in it, and in acting upon it within reasonable limits. And we marvel that facts so simple and of such easy comprehension and yet of such practical value should receive so little attention from the writers on ore deposits.

THE RELATION BETWEEN RECENT INDUSTRIAL PROGRESS AND EDUCATIONAL ADVANCE

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WRITERS and students who have turned their attention to educational problems have almost without exception given adherence to what may be called the "great-man" theory of educational progress. They have maintained the thesis that educational advance has been chiefly, if not wholly, due to the efforts and the perseverance of certain great personalities, who have pushed their particular contribution upon a reluctant public, by the sheer force of personal ability and merit. During the first period of great educational activity in the United States, according to this theory, our educational progress was attributed to Horace Mann, Henry Barnard, James G. Carter, Samuel Lewis and others. Without in any way depreciating the value of the labors of these able and earnest men, it is just and proper that recognition be given to the underlying social and economic conditions which produced the situation that enabled them to carry their propaganda to a more or less successful issue; and which, indeed, indicated to them the need of such works and filled them with the zeal and ardor necessary to carry them out in the face of determined and powerful opposition. Mann and his associates exercised a "directive," as Lester Ward expresses it, influence; but a further search must be made for the "impelling" forces. Only when the student comes to the more recent period of manual, scientific and commercial training, and of recreational education, does he find any important recognition of the underlying influence of social and industrial changes. Even in this period little has been done except to point out in a general and casual way, the fact that industrial progress and the growth of cities have led to many hap-hazard additions to the curriculum, and have been the real cause of bitter conflicts between the "reformers" or "fadists," and the "conservatives." The reformer, educational or otherwise, is a product of his time; if he is successful, it is because he has, in a measure, correctly interpreted the hitherto vague and undefined demands of the classes of people which are rapidly rising in influence and importance.

The many striking and important social and industrial changes which have occurred during the last two or three decades, make many new demands upon our educational system. In recent years the broad conception of education as a lifelong process has been generally accepted. It is no longer conceived to be solely confined within the walls of school, college or university. Many different agencies,—the home, the playground, the press, the pulpit, the lecture platform, the library, the labor union, the store, the shop, the farm, the office, the society—all supplement and complete the work of the school. In considering the duty and work of our public school system at the present time, or at any other period, attention should be paid to the functions which these other institutions are able to perform at the time under consideration. The school is normally a time and labor-saving device, as well as an institution which forms the character and aids in the development of the individual, and in the progress of society. It should convey to the student the accumulated experience of past generations, it ought to show the significance of his daily experience, and coordinate the latter with his studies and investigations; it ought to train him so that he can and will wish to continue his education by the aid of these other secondary educational agencies; and lastly, but not least, it should attempt to supply any deficiencies which change may develop in any one or all of these other agencies. The real function of the school is to adjust the individual to his environment—physical, industrial and social.

In the study of educational problems at the present time, two important, but often overlooked or neglected, facts confront the investigator. In the first place, the social environment, the sum total of influences which bear upon the life of the individual, has been increased in extent; in other words, the entire world has been drawn closely into touch. People, intelligence, goods, now come from and go to the most distant parts of the globe quickly, surely and regularly. On the other hand, occupations and certain characteristics of home life have changed so as to tend to produce narrow views of life, and to confine the vast majority of individuals within narrow grooves of action and thought; the tendency is to cause him to live in "parenthesis," disconnected from the great world of thought and action. While modern communication and transportation, and world markets demand a broader life and tend to produce broad, liberal views of society and of the world; occupations have been specialized and subdivided until the life of the majority of individuals is cramped. Our daily work and home environment, whether rural or urban, tend to contract and astigmatize our view at the very period when democracy and the idea of a community spirit should thrive and be actually transformed into a reality. This is indeed a grim paradox of modern industrial life.

The earlier forms of industry gave the worker a relatively broad outlook; division of labor and specialization of industries tend to narrow this vision. As the division becomes more and more minute, the production of goods requires the cooperation of a constantly increasing number of workers. Each one forms but a link in a great industrial chain, and consequently sees only a minute part of the entire operation necessary to make the completed article. Machine production aims at making a uniform and interchangeable product. The workman is unfortunately bound down to a rigid and monotonous routine; he becomes in time almost automatic in his movements. He struggles blindly on, working and producing, without recognizing the end in view, without feeling that he, himself, is an integral and necessary factor in the formation and operation of a great industrial machine or organism.

The school must aim to demonstrate the social necessity of each worker's task, and to give a clue to the great, intricate industrial labyrinth. The problem of the relation of labor to capital can not be solved until the work and function of all factors of production are clearly understood by a majority of the people; when such a condition obtains, the question of the proper distribution of wealth will be greatly simplified. The school attempts to meet the new economic condition by enlarging its curriculum; it now aims at more than mere mental training and discipline. Manual training, nature study, kindergartens, athletics, physical training, commerical training, agriculture, domestic science, cooking, sewing, drawing, modeling, painting and music are now incorporated into the course of study. These added features are merely tentative attempts to give training which was formerly provided outside the school, but which can not be so provided under present conditions. Much of this work has been added in a haphazard manner, in order to fill a vaguely defined need, without proper arrangement or agreement with the older portion of the school curriculum. These additions, the direct result in many instances of a vigorous popular demand, have increased the importance of the school, and have made it a more potent factor in the industrial, economic, and social progress of this country. Nevertheless, after this enlargement and enrichment of the course, there still remain many gaps in our educational system which are yet to be bridged over.

The order in which these additions have taken place is fairly well defined. As scientific discoveries and the practical applications of steam and electricity multiplied, our industrial methods underwent an almost complete transformation. A universal need for scientific and technical knowledge was felt. The first notable change from the time honored curriculum was made in response to this demand. The physical sciences, physics and chemistry, were advanced to a position of equal rank with mathematics and language. Next appeared a demand for the kindergarten, manual training, drawing and domestic science. This demand is the result of a conscious or unconscious recognition of the undesirability of a wide separation of hand work from head work, aided by the call of manufacturers for young men possessing trained hands and eyes. The need of such training was not urgent previous to the wide-spread development of the factory system. Treading on the heels of the manual-training movements came physical training, night and vacation schools, training for citizenship, nature study, school gardening, the study of agricultural science, and the special school for the truant and the "incorrigible." Not all of these additions to the work of the school are to be found in any one system, but each has been somewhere recognized as a desirable feature of the educational program. In general, it may be affirmed, that as a people pass from a semi-primitive agricultural stage with isolated, nearly independent families, to the more complex industrial life involving mutual interdependence and specialization of occupation; the importance of the education gained within the school increases relatively to that acquired outside.

What is the significance of these changes to society? It seems indisputable that the importance of the school relative to that of the home in the education of youth, has increased and is still increasing. This fact grows naturally out of the changed functions and environment of the home of the present as compared with that of immediately preceding generations. Home training is highly individualistic; school training is not. The state educates the young in order to advance the welfare of society, in order to form the good citizen—the efficient producer and consumer. The desired result is the elevation of the standard of living of society—a social benefit. The mass can, however, be elevated only by acting upon each individual composing it. The school becomes society's agent for the promotion of its collective welfare; its purpose is chiefly directive. As society is recruited from the young, it is necessary that the incoming generations be worthy successors of the outgoing. The attention should be fixed upon those institutions which train the growing child, and not so much upon those corrective and repressive institutions which are needed because the early training and direction of their inmates were not what they should have been. Too much money is spent upon the diseased tree, but not enough on the growing twig. The functions of the school should include the intellectual, physical, industrial and moral training of the young, and of the older persons as well; the greater the efficiency and effectiveness of the school, the less the need for corrective and repressive institutions.[1]

The cure for many industrial and social ills is to be found in the proper use of increased leisure which improved industrial methods make possible, and which the modern ideal of democracy proclaims to

[1] See article by the writer in *Education*, October, 1903.

be the birthright of each and all. Leisure makes possible study, social intercourse and the expansion of the life of the individual to the measure which the modern world community spirit demands.

At the beginning of the last century, the United States was a weak nation possessing an unknown immensity of undeveloped resources. In a century it grew to be one of the richest and most powerful nations of the earth—an acknowledged great power. Development of resources was the demand and the necessity of the period. Exploitation of natural treasures and constant expansion was the program of the century. Resourceful, self-reliant and individualistic men who were willing and able to devote untiring energy to the task of building up the material strength and resources of the nation, were needed, and became the familiar, successful and progressive type of American manhood. The fundamental, all-absorbing economic question was production, which was carried on chiefly through the exploitation of natural resources. The rough and crude form of frontier life reacted upon the entire people, and left an imprint which many generations will not entirely eradicate. As long as the frontier remained there was continual contact with the new and primitive. This type of civilization tended to continue and to perpetuate itself long after the conditions which caused it had passed into history. The primitive type of society is highly individualistic; it resents the interference of organized society in any form. In such a community might often spells right. It places little or no limitation upon the use or abuse of property. The right of the individual completely over-towers the right of society.

After the disappearance of the frontier a different set of conditions confronts the people of the United States. Widely separated farming communities or sparsely settled mining districts, and the presence of immense tracts of practically free land, demand one system of ethics, one code of human relations, and one kind of educational principles and precepts; while densely populated cities, the scarcity of free land, and increased mutual interdependence make imperative a new scheme of social relations. The disappearance of the frontier induces a weakening of the individualistic and a strengthening of the social qualities of the American people. Sociological, as well as psychological, principles begin gradually and timidly to creep into the educational world. Society must adjust itself to a more crowded environment; and the problem is to make this adjustment along the lines of least resistance. New social, industrial, agricultural, commercial, educational, ethical and legal forms now become necessary. What is desirable and even highly commendable in a new, fertile, undeveloped and expanding country may become a positive menace and hindrance in an older, better developed and more densely populated nation. New aims and new ideals are requisite to this adjustment from the old to the new. Education now assumes a position of greater importance than it held in former generations. Changed environment, crowded cities, more intensive and more scientific agriculture, quicker and more regular methods of transportation and communication are producing effects which are plainly noticeable in the life, thought and action of the entire nation. It is, however, extremely difficult for a people schooled for generations in the university of self-reliance and of individual liberty to graciously accept the restrictions and modifications which this new era makes necessary; but such acceptance is inevitable. If education lags behind, rather than precedes, this changing sentiment, if it is merely passively carried along with the stream, instead of actively aiding in controlling its progress and direction; it fails utterly to effectively perform one of its most important duties—that of minimizing the friction of readjustment to a new environment and a new set of social and industrial conditions. This need of adjustment should be recognized by educators, and intelligently dealt with.

The men of the present are not Robinson Crusoes, they live in a busy world peopled with millions of other similar fellow creatures. An individual is what he is because of the existence and influence of other men; he is distinctly a social product. Development of the individual is the resultant of individualistic and of social demands; but the latter are now beginning to take precedence over the former. Purely psychological and individualistic needs and desires must more and more be modified by those of a sociological character. Society is a complex and delicate organism or piece of mechanism; the wishes and ambitions of the individual must, in an increasing measure, be subordinated to and dovetailed into, the needs of society considered as a whole.

The disappearance of the frontier leads to the gradual elevation of the moral tone of the people. It is an important factor in assigning greater importance to questions of distribution and consumption. Business and political ideals are higher to-day than formerly. Many political methods which were in vogue as late as 1896, are not considered to be in good form to-day. The doctrine that property is a social trust is gaining ground as it could not have done twenty or forty years ago. We are examining closely the methods employed in wealth production. The monopolist and the men of great wealth are now put on the defensive. Each must justify the social utility of his industrial power or his amassed fortune. Race solidarity and the brotherhood of men are now shibboleths. This spirit of brotherhood is first manifested between members of the same trade or society—comparatively small groups; but gradually it enlarges its scope and becomes more inclusive. To-day the laboring man is found preaching the solidarity and mutual interest of all workers in the United States—skilled and unskilled alike. A great strike is conducted upon a clear recognition of this principle, one which could hardly have risen into consciousness if a great mass of fertile and easily accessible land was still our national heritage. Such a change as this calls insistently for new ideals in education.

America is an enormous assimilative cauldron. Here are gathered nearly all the tribes and peoples of the earth in one great heterogeneous mass; and the public-school system is the official assimilator. It deals with the young and plastic. Excepting those who attend private and parochial schools, our laws bring all the children of the entire country under the influence of the public school system. The immigrant comes to us from an entirely different environment; he has developed under different influences. His home life is not the same as ours; his child possesses other concepts, traits and ideals than those of the American boy or girl. The process of assimilation usually means the molding of this people in conformity to the so-called Anglo-Saxon cast. It is forgotten that these people have many characteristics and traits which might well be grafted into our civilization and thus perpetuated. Miss Jane Addams has done much to emphasize this important fact. She points out that it is characteristic American "complacency" to utterly ignore the past experience of the immigrant who comes to our shores. Earnest Crosby makes the indictment more sweeping and severe: "And not content with stifling the originality of the immigrant, we must needs carry our missionary zeal for uniformity to foreign lands in the hope of destroying all individuality. In Anglo-Saxonizing India and Japan we are crushing out the most wonderful of arts beyond a possibility of resurrection. We are the Goths and Vandals of the day. We are the Tartars and the Turks. And the countries which we overrun have each their own priceless heritage of art and legend which we ruthlessly stamp underfoot." Some attempt certainly should be made to preserve and continue the desirable traits and gifts of the different alien peoples who crowd to our shores; and to assimilate these traits into the sum total of our national characteristics. Few educators have as yet seen the possibilities and the desirability of progress in this direction.

It should be noticed that not until after our frontier was practically a thing of historical significance only, did the immigration from Southern Europe begin. These people lack individual initiative; they live in little communities. With the rise of modern industrialism and of urban life, our civilization took on aspects which were attractive to the more docile and less individualistic emigrant of many sections of Europe. The traits of these people are more nearly consonant with the life of to-day than that of the early individualistic Anglo-Saxon frontiersman. The assimilation of these races and of their culture may modify our civilization and traits in a very desirable manner. A Greek immigrant, in a letter recently published,[2] clearly states the proposition. "In this country there is a great movement against the foreigners and especially those of Latin, Slavic and Jewish origin. The Latin and Jew (altruist and sentimentalist) will give in this country some of their qualities that the northern people don't have. The Americans (egoists and individualists) need some of our blood to change their character in the next generation." There is, however, another side to this question which will be touched upon later.

The rapid growth of cities has been a marked feature of recent growth and development. The city of to-day is the result of a rapid and unhealthy growth. People have been rudely drawn from a rural environment and quickly sucked into these great uneasy vortices of industry and trade. The ideals, customs and habits of the rural community have gone with them to this new environment, and still cling with great tenacity. Only in recent years have the city dwellers awakened to the fact that they are really dwelling in an environment which calls for new, non-rural rules of action and of association. The nature of the city itself has been modified. It is larger, more crowded, more dependent upon arteries of trade and transportation, and upon the supplies furnished from the outside. The race must adapt itself to urban conditions as they exist to-day; we must learn to live and to thrive in densely populated centers. If the United States is to continue on its present course of advancement and progress, the city must be made clean, healthy, moral, and it must be well governed. The majority of the successful business and professional men of to-day were born in rural districts. In the past the country has furnished the bone and sinew of the city, and, as a necessary consequence, it has been drained of many of its best and most progressive citizens. The city can not indefinitely continue its parasitic existence. Already one third of our population are urban dwellers. A much larger percentage of our successful and progressive men and women must in the future be drawn from the city-born and city-bred population; hence, the urgent need of improved conditions in our cities.

The modern city is a mere industrial establishment; but it must be made a cluster of homes. Healthy and wholesome home surroundings can only be obtained through education as to the sanitary and esthetic requirements of urban communities; and these efforts must begin with the child. The cities have been "great sores upon the body politic," because they have experienced such a rapid development that society has been unable to modify itself rapidly and sufficiently to meet the requirements of the situation. A two-fold weakness of our educational system is revealed at this point. The curriculum and the methods of the city school have not been sufficiently modified to meet the require-

[2] *Arena*, March, 1905.

ments of children, living in a crowded city, with little opportunity for constructive work or healthful recreation. Some progress has been made in this direction; but there is still great need of further improvement. On the other hand, the rural school has assisted in augmenting the growth of the cities and in encouraging the drift away from the farm. Its curriculum has absolutely ignored, with a few very recent exceptions, the fact that the farm presents problems which require education and training to solve. "Every book they [the country children] study leads to the city; every ambition they receive inspires them to run away from the country; the things they read about are city things; the greatness they dream about is city greatness." The problems connected with the city, those relating to labor, and all our great industrial and social questions, are at the root questions of education.

However, after the faults of the city have been examined and laid bare, it is but just to recall that the cities have ever stood in the forefront of the educational advance and in the development of labor organizations. Our free tax-supported schools, for example, originated in the cities. A striking illustration of the position of the cities is found in the result of the referendum of 1849, which established free schools throughout the state of New York. Forty-two out of a total of fifty-nine counties favored the repeal. Of the seventeen counties which stood firm and won a victory for the tax-supported public school, four were included in, or were directly adjacent to, New York City, eight bordered the Hudson between Albany and New York, and three others contained the important cities of Buffalo, Syracuse and Schenectady. The vote revealed a sharp division of urban against rural counties; and the former stood for progress and for better educational facilities. Without entering exhaustively into an analysis of the situation, five reasons may be assigned for this phenomenon which is by no means confined to the Empire State: (*a*) A large percentage of our city population are industrial workers who are small or non-taxpayers. (*b*) In the large cities are found great masses of accumulated wealth which can be taxed. (*c*) Here the home first lost its industrial character and its surrounding playground, and as a result much of its educational possibilities. (*d*) People are crowded closely together in cities, evils and needs are more in evidence than in rural districts. Also, the opportunities for agitation and propaganda are more numerous. (*e*) Pauperism and juvenile crime are more prevalent and disturbing in cities than in the country.

Industrial progress has brought about the separation of the workers into distinct, well-defined classes; particularly marked is the division between the manual workers and the brain workers or the managers of the business. Professor Veblen remarks that the progress of industry has relieved one class of workers, "of the cares of business"; and they "have with increasing specialization given their attention to the mechanical processes involved in the production for the market." The remarkable increase of the indirect method of labor is a factor in the modern industrial problem. The workers no longer produce directly to satisfy their own wants; each produces for others, while all furnish something for each individual. It is a round-about process; the connection between effort and satisfaction is hidden. The direct reaction between effort and satisfaction has been superseded by a very complex social and industrial chain of actions and reactions. The worker often becomes a drudge, a drone, an unthinking piece of mechanism, partially because he does not recognize or feel that his work has any social significance, because there is little apparent causal relation between effort and wages. Industry has been "depersonalized."

Modern specialization of industry, diversification of demands, and increase in the variety of consumption have tended to divide the population into a large number of classes and interests. Progress has always resulted from class struggles, the clash of interests; but to-day the form of this contest has become complex. There are the familiar traditional classes—land-owners, manufacturers, merchants, professional men and laborers; but each one of these classes is now split into subgroups, on the one hand, while, on the other, many individuals may be classed under two or more classes or sub-classes. Nevertheless, many difficulties and obstructions now face the workman who aspires to become an employer, who struggles to rise out of his class. John Mitchell believes that the workers are, as a rule, acting on the principle that they can not rise out of that class. For the vast majority it is once a wage-earner, always a wage-earner. The amount of capital now required to set up in nearly every business is large. Even the farmer who runs in debt for his farm, finds it almost impossible to pay off the mortgage from the profits of the farm in many sections of this country. The amount of money required to enter the iron and steel business is measured by hundreds of thousands or millions of dollars. Consolidation of business interests reduces the numbers of managers and superintendents. The great industrial concerns and the railroads are becoming large civil-service systems. A man must enter their employ in his youth, at the bottom, remain with the company year after year, gradually working into better-paid and more responsible positions. But he always remains an employee. The young man can no longer work hard for a few years, save a few hundreds or thousands of dollars, and then set up in business as an employer of others, many of whom will follow in his footsteps within a few years. The person who now accumulates a small amount of property is obliged to turn the management of it over to others. Investments in stocks and bonds, deposits in savings-banks, insurance, and like modes of investing property, take the place of investment in landed property or in a business managed by the property owner. Management by proxy becomes the rule, not the exception. The corporate form of business requires the concentration of large amounts of property under the control of a chosen few. The savings-bank, for example, is merely a collective form of investing in which the investments are made by the banker rather than by the hundreds of small investors themselves. The discipline that comes from the care and management of property is lost on the great multitude of workers of to-day.

Also, coincident with this phenomenon is the above-mentioned change in the character of the multitudes of immigrants who are flocking to our shores. In the report of the Commissioner-General of Immigration, for 1904, an official of the bureau who has been conducting extensive investigations in Europe, writes from there as follows: "The average immigrant of to-day is sadly lacking in that courage, intelligence and initiative which characterized the European people who settled in the western states during the eighties." The personal initiative, adaptability and self-reliance of the American have ever been the pride of the nation; but the environment, business methods and opportunities which aided in the production of these characteristics are undergoing modification. Industry and commerce offer opportunity to only a few, for the development of these valuable traits; and immigration brings us a class of people who are also sadly deficient in these qualities.

"The machine process is a severe and insistent disciplinarian in point of intelligence. It requires close and unremitting thought, but it is thought which runs in standard terms of quantitative precision. Broadly, other intelligence on the part of the workman is useless, or it is even worse than useless."[3] Unfortunately under present conditions, the above quotation states what is true in many cases of subdivided labor. Extreme subdivision of labor has reduced the unskilled worker to the level of an automatic piece of machinery. Brains, ideals, everything which go to make up the real human being and to differentiate him from the automatic machine, are at a discount. The man becomes a "hand." The internal organization is now placed on a scientific, calculated basis. Time cards and exact methods of determining the cost of labor and material are now essential to every well-regulated business. Every step from the first displacement of the raw material until the finished product is in the hands of the consumer is carefully calculated.

The chief motive for subdivision of labor is given by the opportunity to hire unskilled, low-standard-of-living workers, at an extremely

[3] Veblen, "Theory of Business Enterprise," p. 308.

low wage. "Thus division of labor is, in the last analysis, nothing but one of those processes of adaptation that play so great a part in the evolutionary history of the whole inhabited world: adaptation of the tasks of labor to the variety of human powers, adaptation of individuals to the tasks to be performed, continued differentiation of the one and of the other."[4] But, if this differentiation is carried so far as to tie the individuals down to such a narrow routine as to prevent their rising in the scale of life, it is a bar to human progress. The immigrant is one of the causes of subdivision of labor. Where labor unions are strong enough to establish a minimum wage, some modifications may be looked for; but the question which society must face is: Can society afford to allow certain of its members to be reduced to the condition of human automatons? If it is held that certain classes in the community can not be improved or raised to a higher level, then indeed the caste form of society is treading close upon the heels of the American people.

Division of labor, perhaps even minute subdivision of labor, may be considered to be a permanent factor in industry. Modern industry is more productive, many times more productive, per worker, than the older, more simple forms; and as a result a shorter working day is allowed the worker. This grinding, unvarying, monotonous, joyless sort of working period should be balanced by broader social life, by better, more elevating use of leisure time. In short, as one's work becomes exact and narrowing, one's leisure time should bring variety and breadth of experience. The suffrage has been extended to practically all the male population over twenty-one years of age; but in order to exercise the franchise intelligently, as was recognized in the days of Plato and Aristotle, the citizen must have leisure time to study and discuss the social and political problems of the day. If this leisure time is not properly or wisely utilized; the "boss" and the "machine" flourish. The great multiplicity of clashing interests also offers opportunity for the shrewd and unscrupulous politician to play interest against interest, and to win political control and personal gain through careful manipulation. In any industrial democracy, the problem of the utilization of leisure becomes one of the important and vital problems.

Looking at education from a purely economic point of view, aside from ethical considerations, the aim should be to develop not only more efficient producers, but also more efficient consumers. All men must be considered from the side of consumption as well as of production. The end and aim of normal economic activity is consumption of economic goods. Other things being equal, consumption should be directed toward those articles which the country is best adapted to produce; it should also be directed away from the excessive demand for the raw

[4] Bücher, "Industrial Evolution," p. 299.

and crude economic goods, toward a greater variety in quantity and quality of demands. As Clark has shown, the tendency of dynamic economics, as seen from the purely economic point of view, is toward variety in consumption and specialization in production. But after a certain point is past specialization in production tends to prevent greater variety in consumption. These economic considerations, as well as those of an ethical or social nature, set bounds beyond which specialization ought not to pass. This limit is not fixed and invariable. For example, the man who has an avocation, who utilizes his leisure in such a way as to broaden his view of life, so as to exercise many different sets of muscles and brain cells, may specialize his work much more minutely without individual detriment or economic and social loss, than the man who talks shop, or does nothing to diversify his tastes or to open up new lines of thought and action, during his leisure hours. In the terms employed by the economist, the ideal point of equilibrium is where the descending curve of the social value of the products due to additional subdivision is met by the ascending curve of disutility due to long-continued and narrow specialization on the part of the individual members of society. Other things remaining the same, the additional products which come into being through increasing subdivision, gradually diminish in value as increment after increment is added, according to the well-known law of diminishing returns; and on the contrary the detriment to society as a whole increases as individuals are forced into narrower and narrower rounds of duty.

Ethical considerations lead directly and unequivocally to the conviction that men must not be treated as machines, that the true end and aim of industry is the production of men, not the multiplication of profits. True long-run economic aims coincide with ethical ideals. As Walt Whitman has taught us: "Produce great men, the rest follows." Primitive industry was always a means to an end which was plainly seen; it was never an end in itself. It has remained for modern times to heap up complexity, confusion, and cross-purposes until the fundamentals have been hidden from view. When the methods of modern complex industry come into collision with the true economic and ethical demands of society, the former must be modified. It is one of the functions of education to harmonize the demands of these two apparently conflicting and opposing forces. It should so train the members of society as to allow the greatest possible advantage to be taken of efficient productive methods consistent with the welfare and best development of the individual members of society of all classes and conditions.

Both the internal and external organization of industry now tend to remove variety, irregularity, risk, chance and speculation. The business of the future calls for the manager and the administrator rather than the speculator or the promoter, for the steady, routinized, narrowly specialized worker rather than all-round men so familiar in the early industrial history of the United States. The traits of the pioneer, the backwoodsman and the hunter, those traits due to varied and changing experiences of the early settler, continue, however, and are transmitted from generation to generation long after the stimuli which produced them have ceased to act and have been overwhelmed by the rising tide of civilization. If modern life offers inadequate opportunity in the ordinary course of daily life for the expression of these inherited impulses, if they are inhibited from all beneficial or desirable expression, they will find expression in abnormal or undesirable ways. Gambling, sport of all kinds, drinking, carousing, are some of the many forms in which these inhibited traits find a vent. The assimilation of the recent immigration will dilute and diminish the strength of these characteristics; but they should not be smothered and cast aside, they should be utilized and turned into new and modern channels of activity.

Mr. John A. Hobson in a recent article touches upon this point. "The factory employee, the shop assistant, the office clerk, the most typical members of modern industrial society, find an oppressive burden of uninteresting order, of mechanism, in their working day. Their work affords no considerable scope for spontaneity, self-expression and the interest, achievement and surprise which are ordinary human qualities. It is easily admitted that an absolutely ordered (however well ordered) human life would be vacant of interest and intolerable; in other words it is a prime condition of humanity that the unexpected in the form of happening and achievement should be represented in every life. Art in its widest sense, as interested effort of production, and play as interested but unproductive effort, are essential."[5] If modern industrial and commercial life is being placed upon a stable, sure, scientific, calculable basis, if chance and luck are being replaced by skill and efficiency, if routine and dead uniformity are replacing all-round effort and variety, if the home environment is becoming more monotonous and artificial; other social institutions must furnish pleasurable change and variety. If elevating institutions as the school or the church do not cope satisfactorily with the situation; other much less desirable ones will, and the spirit of gambling, of riotous living, of carousal, of living for the sake of sport, will enter society and take a firm hold. Old instincts are not easily eradicated; education must never overlook them. The recent additions and contemplated additions to our educational system are the concrete results of some of the

[5] *International Journal of Ethics*, January, 1905.

attempts which have been made to cope with the question in a more or less intelligent manner.

The entrance of the United States and other important industrial nations upon a policy of commercial expansion, the growth of imperialism and the prevalence of the desire to exploit the less industrially progressive nations, mark the beginning of a new epoch in our national life. Specialization of industry and subdivision of labor now assume new aspects. Capital becomes international; while labor still remains upon a national basis. Mr. Hobson and others have pointed out that the backward nations will now assume the place hitherto occupied by the great mass of the unskilled in the home country. Humanitarian and democratic tendencies are in danger of receiving a check. Capital in a new, rapidly developing country finds opportunity for investments in improvements; but in a more highly developed, but still progressive country, it is obliged, unless there are opportunities for investments in foreign countries, to seek investment in directly productive enterprises which produce articles for the consumption of the great mass of the people. If there is no opportunity for foreign investment of capital, industrial progress will necessitate an improvement in the consumptive power of the masses. Economic and ethical aims begin to draw into closer relationship. The possibility of enormous investments of capital in South America and Asia is something which threatens to affect the industrial, social and educational welfare of the American people. "Once encompass China with a network of railroads and steamer services, the size of the labor market to be tapped is so stupendous that it might well absorb in its development all the spare capital and business energy the advanced European nations and the United States can supply for generations."[6] China and the Chinese workers are a danger because of the low standards of living which prevail in the Asiatic nation, and the consequent ease with which the Chinese people may be exploited. If increased manufacturing and commercial activity in China is not accompanied by a corresponding increase in the standard of living, the American farmer and the American workman are doubtless imperilled by the situation. The educational movement of the last two or three decades is essentially a working class movement; and its future is bound up in the welfare of the industrial and agricultural classes.

[6] Hobson, "Imperialism," p. 334.

THE DAWN OF QUADRUPEDS IN NORTH AMERICA

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IN the early days of the physical sciences one who gave a commonsense interpretation to a phenomenon of nature was looked upon as dissenting from the accepted interpretation of things. It pleased the people of the early days of science to regard natural phenomena as something wonderful, as a divine creation or as something beyond the comprehension of the human intellect. It has been less than two centuries since men began to emerge from under this pall. The advance made in science constitutes one of the wonders of the age. It is the purpose of this essay to record the progress of investigation in one line of scientific research, and that is the one which leads up to a knowledge of the ancestry of one group of the vertebrates.

The early observers of nature had curious suppositions in regard to the nature of fossils. They regarded these objects, which were common, as of various origins. Some claimed that they arose spontaneously in the rocks, others were of the opinion that they arose from germs which had fallen from heaven, but the large majority believed the fossils to be the remains of "an accursed race" whose existence had been ended by the Noachian deluge. Early in the seventeenth century collectors of natural objects became familiar with certain bodies which were known as "glossopetræ." They were embedded in the rocks and the manner of their entombment was a matter of considerable dispute. In the first half of the seventeenth century, Fabio Colonna had tried to convince his contemporaries that the "glossopetræ" were nothing but shark's teeth. His arguments failed to carry conviction, however. It was not until 1669 that Steno, a Dane by birth, though a teacher in the schools of Florence, Italy, demonstrated by the dissection of a common shark's head that the "glossopetræ" and the teeth of the shark were identical. These results he published in a quaint little volume entitled "De Solido intra Solidum naturaliter contento."[1] This was the first application of the modern method of paleontological research to the study of objects contained in the rocks. Later Cuvier continued and extended the researches of Steno and from the time of the famous investigator, Cuvier, to the present, our knowledge of the objects entombed in the rocks has progressed rapidly.

Modern researches have carried our knowledge of the distribution

[1] Huxley, T. H., 1881, "Science and Hebrew Tradition Essays," p. 29.

and relationships of animals farther and farther back into geological time. There was a time, not many decades ago, when people knew nothing of the animals of the ancient days. During the life of Cuvier the knowledge of extinct animals had not progressed much farther back into geological time than the Cretaceous or Jurassic. It was just four years before his death that Jaeger made his important contribution to the Triassic fauna of Europe by the description of the remains of *Mastodonsaurus,* which he had in 1824 described as *Ichthyosauri.* Subsequent researches by a host of observers have carried our knowledge of animals into an antiquity which had not been expected.

The animals which it is our purpose to treat here are the ancestors of the modern Amphibia. There are few groups of vertebrates whose phylogeny is more obscure than that of our common toads, frogs and salamanders. It is the popular idea that these animals are unknown back in geological time, but that they are of a rather recent origin. As a matter of fact the present-day amphibians are the descendants of the oldest group of vertebrated animals with the exception of the fishes. Our knowledge of the fishes begins near the dawn of animal life on earth, and their remains are preserved in the rocks of the Ordovician age, just west of Cañon City, Colorado, and in the Big Horn Mountains, Wyoming. Our knowledge of the amphibians begins just two ages later, and in the Devonian rocks of Pennsylvania are found the earliest traces of quadrupeds on earth. These evidences consist in footprints found by Isaac Lea in 1849 and the announcement of his discovery was given to the British Association for the Advancement of Science by Buckland in that year. These footprints represent a rather large animal which may have attained a length of several feet. The footprints were found impressed in the "Old Red Sandstone" of Pennsylvania which forms a part of the Catskill formation of that state. Marsh, forty-seven years later, announced the discovery of similar footprints from the same horizon and near the same locality but does not mention the discoveries of Lea. From these tracks in the Devonian to the deposits in the Allegheny series of the Pennsylvanian our knowledge of the Amphibia is a blank. There is not a trace recorded of any amphibians in the rocks of the Mississippian or in the Pottsville of the Pennsylvanian.

In the Allegheny series, there are several deposits in the United States, and probably one in Canada, which have produced remains of the early quadrupeds. The principal localities are in Illinois, Pennsylvania and Ohio. From the last named state great numbers of these paleontological treasures have been recovered and are preserved in the museums of the east. The most interesting place which has kept for us a record of the amphibian life of this far-off time is a deposit of coal in the eastern part of Ohio in the northern part of Jefferson county.

These deposits are in the form of a thick bed of coal which has been opened up by modern industry which has cast aside as useless the blocks on which are preserved the priceless relics of the creatures of this bygone time. There have been great numbers of these blocks of coal collected by geologists, but in all probability the greater part of the animal remains preserved in the coal has gone to furnish heat for the people of the region.

The animals, which have been obtained from the old Diamond mine near the village of Linton, Ohio, are imbedded in the coal which formed from the vegetation growing on the shores of the lake in which the coal accumulated.[2] This old lake was probably of but limited extent and may not have measured more than six miles in its greatest diameter. In this lake lived and died for ages the animals whose remains represent the first recorded appearance of quadrupeds on the earth. There are, to be sure, deposits in Illinois which are of contemporaneous age, but so far only five specimens of amphibia have been discovered in these deposits, so they are hardly to be taken into account when compared to the hundreds of specimens obtained by Dr. J. S. Newberry from the Linton locality. The animals which disported themselves in this old lake, at their death fell to the bottom and their remains, what was left of them after their former companions had feasted on their bodies, were covered with the mud and vegetation which drifted in upon them. Thus they are preserved to us.

The student of these remains finds them greatly different from the amphibians of to-day. There were some forms which were large, but the majority of them were small. Some may have reached a length of ten feet while a great many did not exceed six inches and a few were less than five in extent. There is one little form from Illinois, to be described further on, which barely attained a length of two inches in the adult state. Some of the Amphibia from the Linton mines represent snake-like forms with the proportions of the modern whip snake of the western plains, though not with its dimensions. Others more nearly resembled the modern lizards and this resemblance was carried to the extent of the possession of strong teeth and clawed digits. There was no osseous carpus and tarsus, however, so that they are distinct from the lizards structurally. Still other of these early quadrupeds must have resembled the modern crocodiles in appearance and a few may have attained nearly the dimensions of these forms. There were forms which were partially protected by hard dermal plates, at least on some parts of the body. Some, like the fishes, had rounded scales which covered the entire body, while a few appear to have been entirely naked. All the forms appear to have possessed the ventral armor of dermosseous rods or scutes which protected the abdomen much as the abdomen of the *Sphenodon* of New Zealand is protected to-day.

[2] Newberry, J. S., 1889, Monograph U. S. G. S., Vol. XVI., p. 211.

When in the later ages of the existence of this old lake its waters became filled with vegetation and it had acquired the characters of a marsh there came a disturbance in the earth's crust and the lake was again submerged, and on its bottom was formed the thick stratum of good coal which is now known to geologists as the "Ohio No. 6." This coal was formed over the graves of the earliest quadrupeds. Here through the vast stretches of geological time they lay in their coaly bed. After many, many eons of time the descendants of animals which had been their contemporaries came with tools fashioned with their fore feet to dig out the coal to keep their naked bodies warm. These were men and to these miners we owe a debt of gratitude for thus bringing to light these treasures of the earliest quadrupeds.

There was a man in the days when these coal mines were being worked who appreciated the opportunity of collecting the remains of these creatures and he deserves far more credit than the miners who delved in the ground for the coal. This was Dr. J. S. Newberry, whose name is to be ever associated with the first investigators into the history of the primitive quadrupeds of this continent. Through his knowledge of the geology of the region in which the mine was located he realized, as no other did, the importance of gathering these remains as rapidly as possible. The result was worthy of the exertion. The mines have now long since been deserted, the village of Linton has gone out of existence and even the spot where the mines were located is difficult to find, so Dr. Hussakof tells me. Newberry's collection of the early quadrupeds is now in the American Museum of Natural History of New York City, and it will stand as a monument to the zeal of one of the early investigators into the "Eotetrapoda" of North America. Newberry's collections have, for the most part been described by Cope, who has done more on the morphology of the extinct Amphibia than any other investigator in North America.

Dr. Newberry found the first recognized amphibian in the Linton deposits in 1856. The next year Dr. Wyman read a note on the specimen before the meeting of the American Association and the next year he published a description of the form under the name *Raniceps lyelli*. It was necessary to change the name *Raniceps*, so ten years later Dr. Wyman proposed in its stead the term *Pelion* and the form is still known as the *Pelion lyelli* Wyman. This is perhaps one of the most extraordinary of all of the Amphibia which have came from these deposits (Fig. 1). It was thought by Wyman, and later by Cope, that the form had the characters of the modern frogs and in its general appearance it certainly shows great resemblances to the modern frogs, especially in the shape of its head and the length of the hind leg, which Cope seems not to have observed. Among the other forms collected by Newberry is the form shown in Fig. 2. One half of the slab containing

FIG. 1. THE TYPE OF *Pelion lyelli* WYMAN FROM THE CARBONIFEROUS OF OHIO. In the collection of the American Museum. Natural size

the lesser part of the skull went to Dr. Newberry, and in some way the other half of the slab containing the major portion of the cranial elements was obtained by Mr. W. F. E. Gurley and it is now in the collection of the University of Chicago. The illustration is made from the latter specimen. This form is peculiar in the possession of horns which projected backward over the neck. Jaekel suggests that these horns were for the protection of the external gills, but the Microsauria, so far as we know, had no gills, at least in the adult state.

Geologically the record of the amphibians, as it has been given, is the correct one, but chronologically it is not. Long before a single specimen had been taken from the Linton beds Sir William Logan, in 1842, found evidences of amphibians in the Carboniferous of Nova Scotia in some footprints later named by Dawson *Hylopus logani*. These footprints Logan took with him to London and submitted them to the famous paleontologist, Sir Richard Owen, who unhesitatingly pronounced them to be "reptilian." Logan's discovery constitutes the earliest recognition of amphibians in the Carboniferous. A few years later Sir J. W. Dawson and Sir Charles Lyell in breaking apart one of the stumps of the large Sigillariæ came across some interesting vertebrate remains. When the announcement of this discovery was given to the Geological Society of London, the president or secretary remembered a skull which Dawson had sent in three years previously and which had lain in the collection of the society all of this time. Dawson had been delayed one day at Albion, Nova Scotia, and in order to while away the time between trains looked over a pile of rubbish from a coal mine near by. In so doing he split open a large slab of shale in which he found a nearly perfect skull of some unknown animal which he thought might be a fish. This he sent to the Geological Society with other specimens, and it was described in 1853 by Sir Richard Owen as *Raphetes planiceps*, and its relationships were shown to be with the Amphibia. There have been but few remains discovered since at this locality, although it was frequently examined by Dawson.

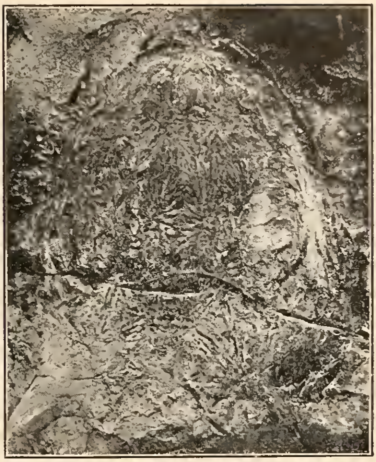


FIG. 2. THE TYPE OF *Stegops divaricata* COPE FROM THE CARBONIFEROUS OF OHIO. In the collection of the University of Chicago. Natural size.

FIG. 3. THE SPECIMEN OF *Amphibamusgrandiceps* COPE FROM THE MAZON CREEK BEDS OF ILLINOIS. In the collection of Mr. L. E. Daniels of La Porte, Indiana. Natural size.

For many years after 1853, Dawson continued his researches into the Amphibia of the Joggins section in Nova Scotia, and he has left us a great amount of knowledge which he collected into his "Acadian Geology" and into his "Air-Breathers of the Coal Period." The forms described by Dawson differed in an essential respect from those discovered in the United States. The animals whose remains occur in the hollow sigillarian stumps in the Joggins deposits, seem to have all been of terrestrial habits, and Dawson frequently speaks of them as "lizard-like" and his restorations of some of the forms, though based on very scanty remains, indicate forms which would be taken for modern lizards. While his restorations are in part fanciful, he has given, in the main, an accurate idea of the animals as indicated by the remains preserved in the old stumps of the swamp in which the animals lived.

Cope's researches into the structure of the early quadrupeds constitute an interesting chapter in the history of the early vertebrates. His researches on the extinct Amphibia began in 1865 by the publication of the description of the form known as *Amphibamus grandiceps*, from the Mazon creek beds of Illinois. This specimen was loaned to the Illinois Geological Survey for Professor Cope to study by Mr. Joseph Even of Morris, Illinois. After Cope's description of the form, the specimen was returned to Mr. Even and, as Mr. L. E. Daniels tells me, it was later destroyed by fire. Mr. Daniels has recently been kind enough to allow me to study a specimen of this form in his collection, the only one, so far as I am aware, now in existence (Fig. 3). The peculiar characters of this form are the possession of sclerotic plates in the eyes and the possession of long curved ribs which have been recently described by Dr. Hay from this same specimen. A specimen of another species from his same deposit has been in the Gurley collection for nearly thirty years. Dr. Newberry saw it when he studied Mr. Gurley's fishes and said in a note that Professor Cope should see it. It was never sent to Cope, however, and it is described elsewhere by the writer as *Micrerpeton caudatum*, gen. et sp. nov. This is a very interesting form, since it shows the impression of the fleshy tail (Fig. 4). On this tail impression are preserved many important structures heretofore unknown for the Branchiosauria to which the form belongs. As such it represents not only the earliest geological evidence of the group, but it is the first appearance of the Branchiosauria in the discoveries in the early quadrupeds in North America. It is a typical branchiosaurian and as such belongs to the family in which the *Branchiosaurus* of Europe is placed.

Between the years 1865 and 1897 Cope continued his investigations on the early quadrupeds and his results are to be found in the proceedings of several learned societies. He early recognized the unusual characters of the Carboniferous fauna, and his many papers attest his interest in the forms which constitute it. He has described all but two of the known Carboniferous species from the deposits of the United States. Among the many peculiar types of amphibians described by Cope none is more bizarre than the form from the Permian of Texas known as *Diplocaulus magnicornis* Cope. This peculiar form has been widely described and commented on. Its affinities are clearly with the Microsauria, and it is one of the latest representatives of that group

FIG. 4. THE TYPE OF *Micrerpeton caudatum* MOODIE FROM THE CARBONIFEROUS OF MAZON CREEK, ILLINOIS. In the collection of the University of Chicago. Twice natural size.

known to us. It is peculiar in the wide horn-like expansions of the skull (Fig. 5). There is no pineal foramen in the dorsum of the skull and it lacks a few of the characters of the other amphibians known from this region.

Interest in the early Amphibia has not slackened in the later years and there have been many contributors to the knowledge of the early forms. There are at present nearly seventy-five species of Carboniferous Amphibia known from North America and as many have been recorded from the Carboniferous and Permian of Europe; many more undoubtedly await discovery. The forms do not differ greatly in their structure in the two continents and each has relatively the same amphibian fauna, although the North American fauna is perhaps somewhat older than the European one. Certainly the Branchiosauria are found

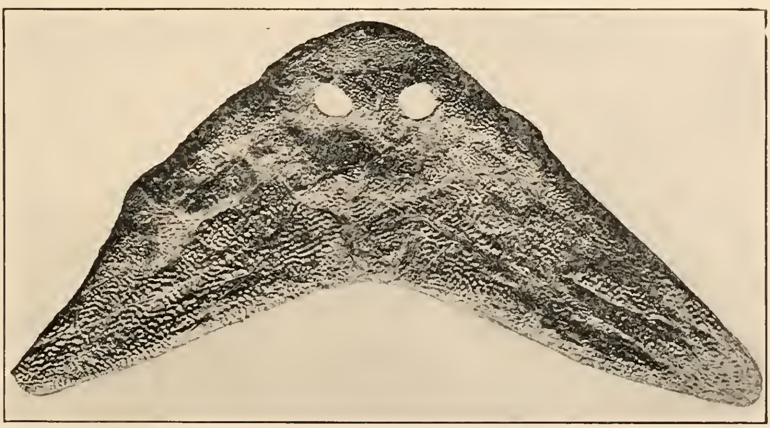


FIG. 5. A SKULL OF *Diplocaulus magnicornis* COPE FROM THE PERMIAN OF TEXAS. In the collection of the University of Chicago. Three tenths natural size.

here in older rocks than in Europe. Among the many forms known may be mentioned some with a peculiar type of vertebra in several allied genera found in Ireland, western Europe and North America; some with fish-like scales over the whole body found in Ireland and Ohio; the presence of the snake-like forms in Ireland, England, western Europe and Ohio and the presence on the continents of Europe and North America of the Branchiosauria already referred to. All of the types of amphibians possess the peculiar ventral armature which was arranged in a chevron pattern over the belly, breast, throat, and even extended, in some cases, out on the limbs.

The earliest quadrupeds, as we know them, form highly specialized groups of organisms which had become differentiated into five distinct lines by the close of the Carboniferous. We must await the progress of discovery to unfold for us the nature of the most primitive quadrupeds from which the earliest known forms have sprung.

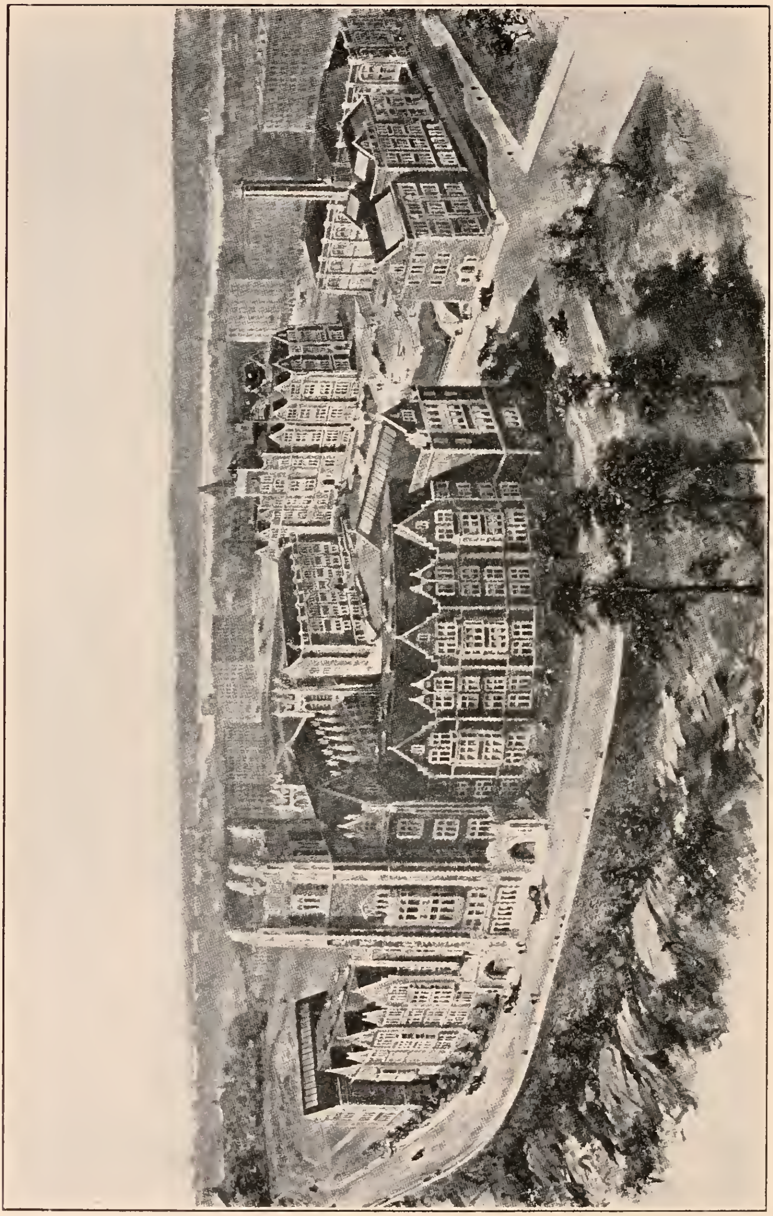
THE PROGRESS OF SCIENCE

THE NATIONAL ACADEMY OF SCIENCES AND THE AMERICAN PHILOSOPHICAL SOCIETY

The scientific meetings held at Washington and Philadelphia during the third week of April offered programs of interest and were pleasant events for those able to attend them. Neither of these societies is exactly in touch with democratic institutions or is able to adjust itself to the differentiation of science, but they have shown in recent years more vitality than might have been expected. The National Academy has taken steps to make its scientific programs of greater general interest and has enlarged its membership, so that instead of at most five new members elected annually there may now be ten. The American Philosophical Society has within the past few years resumed to a certain extent the national character which it possessed when Philadelphia was the chief scientific center of the country. Its annual general meetings bring together a considerable group of men of science from different parts of the country, and the meeting two years ago to celebrate the bicentenary of the birth of Franklin, its founder, was probably the most elaborate and successful scientific celebration ever held in this country.

At the meeting of the National Academy in Washington there were twenty papers on the program, twelve by members and eight on introduction. Several of the papers were elaborately illustrated with the lantern, the most noteworthy slides being the extraordinary enlargements of photographs of cells, showing the chromosomes on which the determination of sex depends, made by Professor E. B. Wilson, of Columbia University. Other illustrated papers were presented by Professor W. M. Davis, of Harvard University, showing standard land forms for a proposed international atlas; by Professor W. B. Scott, of Princeton University, on the age of certain beds in Patagonia, with restorations of Santa Cruz mammals by Mr. C. R. Knight, of the American Museum of Natural History, and by Professor E. L. Mark, of Harvard University, on the Bermuda Biological Station at Agar's Island. Mr. Alexander Agassiz gave an account of the pelagic fauna of Victoria Nyanza and of the elevated reefs of Mombasa and the adjacent coast, and Professor T. C. Chamberlin, of the University of Chicago, described atmospheres supplementary to the one ordinarily considered. Then there were more technical papers. That such papers can be made attractive was shown by the account by Professor W. G. MacCallum, of the Johns Hopkins University, of the parathyroid glands in their relation to tetany and calcium metabolism, and by the paper of Professor F. R. Moulton, of the University of Chicago, on the application of periodic solutions of the problem of three bodies to the motion of the moon. Other events of the meeting were a visit to the newly constructed and admirably equipped geophysical laboratory of the Carnegie Institution, an illustration of which was shown in a recent issue of the MONTHLY, and a lecture on solar research, given under the auspices of the Smithsonian Institution by Professor George E. Hale, of the Mt. Wilson Solar Observatory.

The new members elected were: Edwin Brant Frost, director of the Yerkes Observatory, University of Chicago; William E. Storey, professor of mathematics, Clark University; Edward F. Nichols, professor of physics,



New Buildings of the College of the City of New York.

Columbia University; W. F. Hillebrand, chemist in the U. S. Geological Survey; Wm. B. Clark, professor of geology, the Johns Hopkins University; Whitman Cross, geologist, U. S. Geological Survey; E. G. Conklin, professor of zoology, University of Pennsylvania, professor-elect of biology, Princeton University; Theobald Smith, professor of comparative pathology, Harvard Medical School; Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research.

At Philadelphia the program was twice as long and even more diverse, as the Philosophical Society includes in its scope the historical and philological sciences. Of the forty-two papers presented, it is possible to mention only three or four. Professor C. S. Minot, of Harvard University, discussed the differentiation of the protoplasm of the cell in its relation to reproduction; Professor H. S. Jennings, of the Johns Hopkins University, described experiments on inheritance among the protozoa. Dr. C. B. Davenport, of the Cold Spring Harbor Laboratory, considered the extent to which Mendelian inheritance obtains; and Professors E. T. Reichart and A. P. Brown, of the University of Pennsylvania, showed that the crystals of oxyhemoglobin from the blood of different genera differ, and that even species can be recognized by the crystals. Dr. H. F. Osborn, president of the American Museum of Natural History, gave a lecture on the results of the Museum's explorations in the Fayûm desert of northern Egypt, preceding a reception in the hall of the Pennsylvania Historical Society, and there was a concluding dinner with speeches by the Chinese minister and others.

DEDICATION OF THE NEW BUILDINGS OF THE COLLEGE OF THE CITY OF NEW YORK

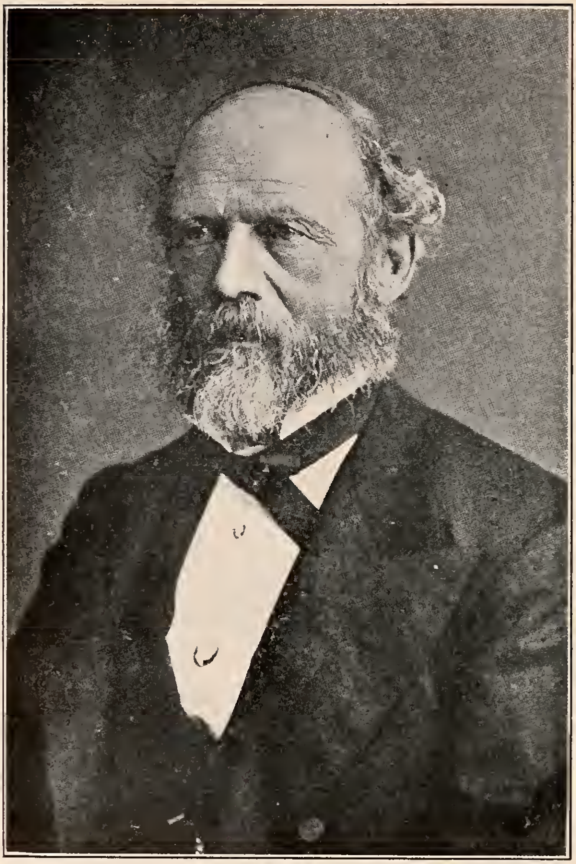
The beautiful and well-planned buildings of the College of the City of New York were dedicated with ceremonies adequate to the event on the fourteenth of May. As shown in the accompanying sketch, drawn by Mr. Richard Rummell, they form a group of buildings such as has rarely if ever before been dedicated at one time to academic purposes. The situation on St. Nicholas Heights equals that of Columbia University, a mile to the south, and is less likely to be marred by the encroachments of shops and apartment houses. An institution of this character, which embodies in its external impressiveness as well as in its work and aims civic duty and pride, represents the best ideals of modern civilization.

The College of the City of New York is maintained by the people of the city for the education of its young men, and is in some respects unparalleled in this country or elsewhere. Philadelphia and Baltimore have high schools of nearly college rank, and Cincinnati has a municipal university, and these four institutions represent a movement likely to become general throughout the country. The College of the City of New York, in view of what it has already accomplished and in view of the great population and wealth of the city, seems destined to take the lead in an educational advance likely to be as important for the next generation as the evolution of the state universities has been for the present generation.

LEWIS HENRY MORGAN

Under the auspices of the National Academy of Sciences there are published biographical memoirs of its deceased members. These documents are of value for the history of science in this country, but are not as widely circulated or as well known as they should be. Just published is a memoir of Lewis Henry Morgan by Mr. W. H. Holmes, chief of the Bureau of American Ethnology, which from several points of view is of special interest.

Morgan, who was born in Aurora,



Lewis Henry Morgan.

N. Y., in 1818, and died in Rochester in 1881, was by profession a lawyer and man of affairs, interested in the first development of the railway system in the middle west, a member of the legislature, both house and senate. He was thus the type of man more usually found among the hereditary upper classes of Great Britain than in our industrial democracy. In view of the increasing specialization of science, there appears to be but little place for the amateur and perhaps this is not to be regretted. But those who begin as amateurs and become serious students with science for their main concern, are selected from large numbers in accordance with interests and talent, and the threatened disappearance of such a group is a serious loss to science.

As a young man Morgan became interested in the League of the Iroquois Indians and an intimate friend of Hasa-no-dú-da, or Ely S. Parker, a Seneca Indian, later commissioner of Indian affairs. He was adopted into a clan of the Seneca nation and admitted fully to its society. His intimate knowledge resulted in the publication of a book on "The League of the Iroquois," the first scientific account of an Indian tribe. Morgan then became well acquainted with the Algonquins and other families and prepared his volume on "Systems of Consanguinity and Affinity of the Human

Family.” This was followed by his important work on “Ancient Society,” which treats the growth of intelligence through inventions and discoveries, of government, of the family and of property. He was also the author of works on “Houses and House-life of the American Algonquins” and on “The American Beaver.”

Morgan bequeathed most of his property to the University of Rochester for the higher education of woman. His anthropological works led him to say: “Democracy in government, brotherhood in society, equality in rights and privileges, and universal education foreshadow the next higher plane of society to which experience, intelligence and knowledge are steadily tending. It will be a revival, in a higher form, of the liberty, equality and fraternity of the ancient gentes.” Morgan was not only a pioneer and leader in the study of the American Indians, but one of the founders of ethnology, a science likely to become dominant in the course of the present century.

THE SARGENT ANNIVERSARY MEDAL

The former students and friends of Dudley Allen Sargent, A.M., Sc.D., M.D., director of the Hemenway Gymnasium, Harvard University, have presented him with a bronze medallion. The medallion, designed by Dr. R. Tait McKenzie, has above the face of Dr. Sargent the words “Dudley Allen Sargent, Pioneer in Physical Education, 1907,” while on the reverse is a row of five Harvard seals below the words, “A Recognition by his Friends and Students.” Two hundred and thirty persons contributed to the medallion fund. A plaster model of the medallion and a bound volume containing the autographs of the contributors to the fund were presented to Dr. Sargent by Dr. Luther Halsey Gulick at the twenty-fifth commencement of the Sargent Normal School of Physical Training held in Sandars Theater, June 1, 1907. The bronze medallion was finished recently and presented to Dr. Sargent. The Sargent medallion committee is having struck a limited number of copies of the medal. These are to be presented to President Roosevelt, Secretary William Taft, Major General Bell, Governor Curtis Guild and Booker T. Washington, who were all students under Dr. Sargent.

SCIENTIFIC ITEMS

We record with regret the death of Dr. Robert Chalmers, of the Canadian

Medal Struck in honor of Dr. Dudley Allen Sargent.

Geological Survey, and of Professor Franz von Leydig, the eminent zoologist of Bonn University.

The body of Emmanuel Swedenbourg has been removed from the Swedish church in London, where it was buried on his death in 1772, and taken by a Swedish man-of-war to Stockholm, where it will be interred.—By the will of Lord Kelvin, Lady Kelvin is appointed sole executrix, and all his property is bequeathed to her. According to the inventory, the value of the property is over $800,000.—The bill providing a pension of $125 monthly each to the widows of Drs. James Carroll and Jesse W. Lazear has passed the congress by a unanimous vote.

Professor Frederick F. Jones, dean of the College of Engineering and Mechanical Arts in the University of Minnesota, has been elected dean of the academic faculty of Yale University. Professor Jones graduated from Yale College in 1884 and has been connected with the University of Minnesota since 1885.—At the University of Wisconsin Professor Carl C. Thomas, now head of the department of marine engineering of Cornell University, has been elected to the professorship of steam engineering made vacant by the death of Storm Bull.

The Boston Society of Natural History has awarded the Walker grand honorary prize of one thousand dollars to Dr. Grove Karl Gilbert, of the United States Geological Survey. This award is made once in five years under the terms of the will of the late William Johnson Walker, a benefactor of the society, "for such scientific investigation or discovery in natural history as the council may think deserving thereof; provided such investigation or discovery shall have first been made known and published in the United States of America." The previous recipients of the Walker grand prize have been: Alexander Agassiz, Joseph Leidy, James Hall, James D. Dana, Samuel H. Scudder and Joel A. Allen.—The Rumford medal of the American Academy of Arts and Sciences has been awarded to Dr. Edward G. Acheson, of Niagara Falls, for his work with the electric furnace.—Dr. William H. Walker, professor of technical chemistry at the Massachusetts Institute of Technology, has been presented by the New York Section of the American Chemical Society with the Nichols medal.

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VOL. LXXII. NO. 1. JANUARY, 1908

THE POPULAR SCIENCE MONTHLY.

EDITED BY J. McKEEN CATTELL

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LANCASTER, PA. GARRISON, N. Y.

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VOL. LXXII. No. 2. FEBRUARY, 1908

THE POPULAR SCIENCE MONTHLY.

EDITED BY J. McKEEN CATTELL

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VOL. LXXII. No. 3. MARCH, 1908

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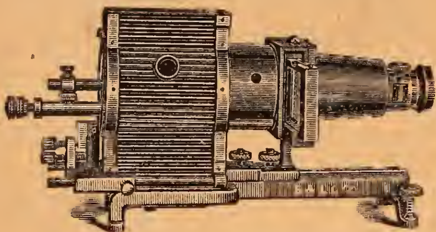

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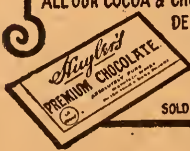

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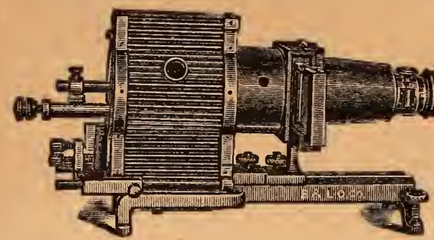

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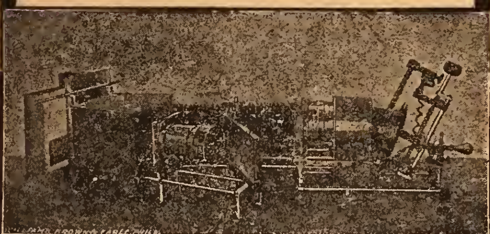

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