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PASTEUR: A STUDY IN GREATNESS

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GREATNESS is a matter of judgment. The degree of worth accorded anything whatsoever is determined solely by the intellectual and moral content of the individual, or the age, that plays the rôle of judge. We speak of great architects, musicians, orators, painters, poets, sculptors, soldiers, statesmen; and cite as examples such men as Wrenn, Beethoven, Demosthenes, Raphael, Homer, Angelo, Cæsar, Bismarck. These men, I say, were great. Why do I say so? Well, the world has pronounced them great. But you ask me, "Have you no grounds for formulating an opinion of your own?" Oh, yes, I have heard rendered the music of many composers; seen the masterpieces of many artists, and so on. And the achievements of none appear to me to surpass those of the men whose names I have mentioned. Perhaps you would name another in each line whom you hold to be more illustrious. You ask me then—"Is there no objective absolute standard by which the achievements of men may be definitely measured?" I answer "None."

You stand before Michel Angelo's "Moses" in the church of St. Peter *in vinculo* at Rome. "This" (you say) "is the finest statue in the world!" Please enlighten me as to the manner by which you have reached your decision. I grant at once that the judgment of the critics coincides with yours; but, of course, you are uninfluenced by that fact. "Is it" (I ask you) "because the statue is a true representation of a real person and event?" You answer—"No, oh no! But it seems to me that a man who dared the wrath of the most powerful potentate in the world; who wrestled with desert, and famine, and pestilence to shape the beginnings of a nation; who talked face to face with God—would have looked like that!" Ah, now you have found *the standard of greatness;* and you perceive that it is an ideal thing.

This being true, is it not remarkable that such unanimity of agreement should have resulted from its application? It appears to predicate the existence of a racial concept of greatness. Undoubtedly this racial idea exists. Philosophers of esthetics have troubled themselves not a little to account for its origination. While considering this elusory problem, the following solution has occurred to me. I offer it as an hypothesis.

An investigation of the specific works accomplished by men ranked great reveals a curious fundamental similarity: *They all relate to the heroic.* That is to say they are either actual deeds which relieved an individual, a community or a nation from danger, or they commemorate such deeds in a masterly way. The favorite theme of poets has always been "*arms, and the man.*" And painters and sculptors have immortalized men whose acts furnish the implied answer to the query of brave Horatius, the keeper of the gate:

> How can a man die better than by facing fearful odds,
> For the ashes of his fathers and the altars of his gods?

By this analysis, the statesman is but the warrior who, with *intellect* as weapon, defends his nation.

If we consider the evolution of human society, it is not difficult to understand how this conception of greatness has grown up and established itself in the subconscious racial mind.

Back yonder in the gray and murky dawn of time, man was not that we see him to-day. Then, indeed, the conditions were exactly reversed; and man—puny, naked, defenceless—cowered in caves, or wandered miserably about seeking the sustenance which his nature demanded, but for the winning of which he was more illy equipped than the beetle that he crushed beneath his heel. Behind every rock, in every bunch of herbage, in every stream and pool, in the air he breathed, in the clouds that rolled above his head, in the glare of the sun, and in the gloom of night lurked death and a thousand dismal terrors.

That the human species escaped extermination at its very beginning is a marvel, and due solely to the one point wherein man is superior to other animals, namely, greater development of the frontal brain wherein lie the centers of memory and language. In that primitive society were some who remembered what things were good for food and where to be found; and so provided against death by poison and famine. Some devised protection against carnivorous animals or enemies of their own kind. These became *head men.* And, on account of their superior knowledge or prowess, they were esteemed while living and revered when dead. The memory of their deeds lived after them in song and story. And so they were gradually transformed from men into heroes and, later, into gods.

Oliver Wendell Holmes, alluding to the influence of heredity, said

"We are but stage-coaches in which all of our ancestors ride." By listening attentively we can hear at any time "ancestral voices prophesying war." This is why the heroic, in act or representation, moves us so profoundly. And this is my explanation of our *racial ideal of greatness.*

The man whose life sketch I now lay before you differed apparently from the traditional hero as widely as the dove from the eagle. He was no sower of dragon's teeth. Instead of sending sword and fire on every side, life, health and prosperity attended his career as the beneficent effects of light accompany the sun. And yet the recital of his bloodless wars and peaceful victories touches the same chords and thrills us with the same emotions as do the exploits of an Alexander.

Louis Pasteur was born at the village of Arbois, near Dole, in the province of Jura, France, on the twenty-seventh day of December, 1822. He died at St. Cloud, near Paris, on the twenty-eighth of September, 1895.

Like Napoleon, Pasteur was the first *ancestor* of his stock. His grandfather was a serf who purchased his own freedom. His father was a tanner who rose to no higher rank than sergeant in the service of the first consul. But he was a man of ability and fine instincts. Believing in the capability of his child to achieve something in the world, he studied diligently in order to assist the lad with his primary studies, and conducted his household with an economy that touched closely upon sacrifice that thereby a collegiate education might be made available for his son.

At fourteen, Pasteur was sent to College of Besançon. He remained there but a half year. Translated suddenly to a wholly strange environment, the shy country boy suffered so much from homesickness that he made little progress in his studies; and his health became so affected that his life was actually endangered. His father was compelled to bring him home. And now for the first time the self denial which had been practised on his account became apparent to the youth. Filled with an agony of shame that he should have so illy requited the love of his family, he resolved that he would spare no resource of his being in an endeavor to retrieve the consequences of his childish folly. The next year he requested his father to enter him at the home college of Arbois, a rural *lycée* little better than a grammar school.

Here he studied diligently, but received no instruction in the subjects which appealed to his nature. The old master assigned to teach the sciences frankly acknowledged that he knew nothing about them. But he allowed the young student access to the limited equipment; and young Pasteur spent much time in laboriously teaching himself some of the elementary principles of physics and chemistry. His teachers considered him slow. Drawing was the only subject in which he attained "honorable mention."

However, the head-master, Romanet, appears to have possessed more discernment than the rest of the faculty; for he frequently engaged young Pasteur in private talks in which he endeavored to arouse in him the ambition to prepare for teaching as a career.

At graduation, he was offered the position of *preparation assistant* or coaching tutor to the younger pupils, a post which carried the munificent salary of 300 francs *per annum* with board and lodging. He accepted the position gladly; and, with charming modesty, expressed the conviction that the salary was much beyond his deserts.

Small as his salary was, still he managed to save out of it something to help educate his sisters. Meanwhile he worked hard on the studies required for his B.S. degree, a prerequisite to his entering the École Normale Supérieure at Paris. On this examination he was graded "mediocre" in chemistry.

Pasteur had thus far been a hard student; but he does not appear to have been an enthusiastic one till he had been for some time at the École Normale under the instruction of Balard, the discoverer of bromine, who was probably the only real teacher he ever had.

But even in this highest school for the training of professors afforded by the France of that day, the scientific equipment was so meager that only a few simple experiments were allowed for repetition by the students of chemistry. An incident in this connection will show the stuff that Pasteur was made of. Not content with being told how phosphorus is prepared, he bought some bones, calcined them, treated the calx with sulphuric acid, distilled the product with charcoal, and placed the distillate in a vial neatly labelled *phosphorus*. This was his first scientific joy. His comrades dubbed him "the laboratory pillar."

About this time he was shown a sample of a strange new acid of the same composition as tartaric acid, but manifesting strikingly different physical characteristics. His curiosity was intensely aroused.

Tartaric acid had been discovered in the "tartar" of wine casks by Scheele, of Sweden, in 1770. Thann, an Alsatian manufacturer of tartaric acid, discovered some of the anomalous variety in the output of his factory in 1825. He was unable to reproduce it. It was studied by Gay Lussac and Berzelius in 1826. The latter proposed for it the name of paratartaric acid; the former suggested that it be called racemic acid. Mitscherlich, of Berlin, in 1844 reported it as isomorphic with tartaric acid; and discovered that while the latter rotates a beam of polarized light to the right, racemic acid is inactive in this respect.

These were the facts brought to Pasteur's attention at the time when he was shown a specimen of the acid. Although immensely interested in the mystery presented by racemic acid, he put it aside, resolving to take it up when through with the final examination of his course of study, an ordeal for which he was just then preparing.

His usual examination fortune attended him upon this occasion. His classmates, who were wise in their generation, merely cramming for the test, came through with flying colors while his name appeared near the bottom of the list. And in the state examination which followed, his name was put next to the last. Apparently his not being rejected was due solely to the excellence which he displayed in the practical phase of the examination wherein the candidates went through the form of actually teaching a class. The lessons in physics and chemistry given by Pasteur caused the jury to declare "he will become an excellent teacher."

He was appointed laboratory assistant to Laurent, the first to formulate an hypothesis of the substitution of hydrogen in hydrocarbons. This theory was elaborated, and enunciated in its final form, by Dumas in 1834. At this time, Laurent was working on sodium tungstate. One day he showed his assistant, under the microscope, some crystals of this salt supposedly pure but which manifested three distinct forms of crystallization. Pasteur began at once to learn how to use the goniometer. In order to master its technique, he made elaborate measurements on *all easily crystallizable tartrates,* thus revealing the fact that his curiosity concerning the two known tartaric acids had remained lively throughout the preceding two years.

In the meantime he was working toward the doctorate, which he achieved August 23, 1847, on the strength of two small papers, the one entitled "Researches on the Saturation Capacities of Arsenious Acid: A Study of the Arsenites of Soda, Potassa and Ammonia," and the other "A Study of the Phenomena Relative to the Polarization of Liquids."

He himself said of these papers, "They are elementary, and little more than programs for future work." Again he attained but poor ranking.

He now desired to study in Germany; but poverty frustrated his plans. On March 20, 1848, he read before the Académie des Sciences a part of a paper on dimorphism which was little more than a catalogue of all known substances crystallizing in two forms. Of itself, one might say that it was almost valueless. But to the student of Pasteur's life it was a proof that his work on the tartrates was still being prosecuted; and it afforded an index pointing out the tenacious purpose and the resolute will of the man.

After a flash of republican ardor in 1848, in which he not only volunteered service but also contributed to the cause all his savings, 150 francs, he returned to his crystals, and soon had the fortune to discover hemihedrism in the tartrates, a fact that had escaped the scrutiny of Mitscherlich and of Provostaye.

So far as his investigations showed, all crystals of tartaric acid had hemihedral faces; but he had found none on the racemates. Conceiving that this aspect of crystals might be an index of their molecular structure, he reasoned that the diverse optical behaviors of solutions of tartaric and racemic acids might be explained by a structural law. On fire with this new idea, he carefully examined a lot of tartrate crystals, and found, as he had anticipated, that each had hemi-hedral facets. He turned now to racemate crystals, expecting to find them destitute of hemihedrism. Imagine his disappointment, therefore, upon finding that here also each crystal distinctly displayed hemihedrism. But upon laboriously going over his work again he discovered a fact that had previously escaped his notice, namely, that the half-form facets of tartaric acid were all turned toward the right while those of the racemates were half right-handed and half left-handed. A new idea flashed into his mind. Carefully picking apart the two kinds of racemate crystals, he made a solution of each and, with anxious mind and throbbing heart, applied the polariscope. The solution of right-handed crystals deflected the beam to the right. They were pure tartaric acid. The solution of left-handed crystals deflected the beam to the left. They were *a new acid—lævo tartaric acid.* He mixed his solutions in equal proportions. The mixture did not affect the beam. *It was racemic acid.*

His excitement was so great that he could not look through the instrument again. Like Archimedes, he exclaimed "I have found it," and rushed into the corridor, where he met an assistant whom he embraced in a transport of joy.

This was one of the most illuminating discoveries known to the history of chemistry up to that time. Measured by its ultimate results, it is doubtless the most far-reaching discovery ever made. Developing in one direction, it was the germ of a new science—stereo-chemistry; in another it transformed medicine and agriculture from empirical practises into true sciences; and incidentally it enriched the world by a number of other discoveries of unparalleled practical value. Done at the age of twenty-five, this first great work of Pasteur's was a prophecy of that brilliant career throughout which he continued to manifest the same marvelous capacity for seeing the unseeable. It led to his appointment at once as professor of chemistry in the college of Dijon.

Finding that the duties of this position consumed all his time in teaching, he asked the government for a transfer to some place which would admit of his going on with research. Quite unexpectedly to himself, he was sent at the beginning of 1849 to the University of Strasburg to relieve Bersoz, professor of chemistry there, who desired to go to Paris.

Realizing fully the value of the vein he had discovered in tartaric acids, he directed his energies along that line. He had found out what para-tartaric, or racemic, acid *is;* but neither he nor any one else knew its origin. He now undertook the discovery of this. In 1852 he visited all the factories of tartaric acid in Germany and Austria, endeavoring to trace the production of racemic acid to its source. He ascertained that the manufacturers generally had an idea that racemic acid was either potassium or magnesium sulphate, and consequently rejected it in the process of refining tartaric acid. This accounted for the limited quantity which had accidentally found its way to the market. As most of the tartars came from the south of Europe, and had been subjected to a preliminary rectification before shipment, it was further evident that but a moiety of racemic acid ever reached the factories. He pushed on his enquiries, visiting factories and vineyards until he positively located it in the crude tartar, where he found, as he had anticipated, that it was produced abundantly simultaneously with tartaric acid in the fermentation of wines. He wrote of this quest "Never was treasure sought, never adored beauty pursued, with greater ardor."

Having located the natural source of racemic acid, Pasteur next undertook to synthesize it from tartaric acid. This appears an easy problem in light of what every student now knows of the methods for effecting hydration, for constitutionally racemic acid differs from tartaric merely in possessing water of crystallization. In June, 1853, he was able to announce the completion of this great work, which had been accomplished by maintaining cinchona tartrate at a high temperature for several hours. This synthetic product was also optically inactive. It is known as meso-tartaric acid, and is the fourth form of the series. This research brought its author the grand prize of the Académie Française, and the ribbon of the Legion of Honor from the government.

Looking now at the tartaric acids, Pasteur's mind took a wider sweep. He saw that they were typical of all living things, which present asymmetry everywhere, and that they themselves were products of a form of life.

While engaged upon the racemates, he had found that the dextro-crystals alone were altered by fermentation, the lævo-forms remaining unchanged in the liquor. "The reason for this," said he, "can only be because this special ferment *feeds,* so to speak, more easily on the dextro-forms."

He pondered this problem long before he saw his way clear to its solution. At the same time he sought to unravel the indicated physiological significance of chemical affinities.

In September, 1854, Pasteur was appointed professor of chemistry and dean of the new faculty of sciences at Lille. Upon taking up his duties, he was greatly hampered at first by lack of facilities. The conditions which he encountered would have disheartened any other man. The scientific equipment consisted of a coke-heated stove with which his room was warmed and one student's microscope. This institution had recently been established by the municipality for the promotion of its industries, which were largely associated with alcohol.

Pasteur at once began the study of fermentation. This was a field which lay enshrouded in darkness with the exception of one tiny ray of light. In 1836, Cagniard de Latour had remarked that yeast, the ferment of beer, was composed of cells which were capable of reproduction by a sort of budding. He expressed the opinion that this microscopic plant probably acted on sugar by some sort of vegetative effect. A similar observation was made about the same time by Schwann, of Germany.

Pasteur set himself the problem of solving the mystery of fermentation. His notes show that he commenced by projecting an hypothesis associating fermentation with the dimorphism he had discovered in tartaric acid, which must have been caused in some way, he thought, by the action of a ferment on the grape juice.

Berzelius, whose ideas then reigned supreme in chemistry, was of the opinion that fermentation is a *catalytic* process. He gave it as his opinion that what de Latour *believed* that he had seen was organic matter precipitated by the process of fermentation, presenting forms *analogous* to vegetable life. Liebig's explanation was equally mystic. He defined fermentation as "action due to influence." He held the opinion that a ferment is a mass of organized matter set free from yeast cells by their death and consequent rupture. Such matter he supposed to consist of unstable molecules which in the act of changing into new molecular arrangements liberated energy which in turn converted molecules of sugar into molecules of alcohol.

Uninfluenced by the metaphysical speculations of these great scientists, Pasteur held to the sure road of experimentation. In August, 1857, he discovered the fermentative organism which sours milk and produces lactic acid. The same year he was transferred to the École Normale Supérieure at Paris. The next year he discovered that glycerine and succinic acid are both produced simultaneously with ethel alcohol when sugar is fermented.

That Pasteur lost no implication of any phase of his researches is shown by a letter to his friend Chappuis written in January, 1860. He says: "I am hoping to mark a decisive step very soon in the celebrated question of the spontaneous generation of life. Already I could speak; but I shall require the accuracy of an arithmetical problem. I intend to attain even that." In a letter to his father, of about the same date, he says: "These results open new vistas to physiology. God grant that by my persevering labors I may bring a little stone to the frail and ill-assured edifice of our knowledge of those deep mysteries, life and death, where all our intellects have so lamentably failed."

The belief that living creatures of both usual and unusual types are continuously being spontaneously generated about us is very ancient in origin. It originated in the superficial observations and non-scientific explanations of our ancestors, and was perpetuated by the authority of great leaders, such as Aristotle and Augustine. Aristotle, whose ideas dominated the world for two thousand years, states explicitly that living beings are generated spontaneously from decomposing carcases. St. Augustine fulminates against the atheism of any who dare deny the doctrine, and cites what he considers irrefutable proofs of it. The alchemists gave recipes for the creation of various animals. Thus, Van Helmont gravely tells us, "You need only close up a dirty shirt with a measure of wheat in order to see mice engendered in it—the strange offspring of the smell of the wheat and the animal ferment attached to the shirt."

However, the more careful observation of a later period had cast discredit upon the traditional view. Thus, it had been shown irrefutably that the stock-proof of the spontaneous generationists—the appearance of maggots in decaying organic matter—was due to the hatching of flies' eggs. But the invention of the microscope, with its revelation of millions of minute forms hitherto unsuspected, revived the doctrine.

The lapse of a year after the letters cited above enabled Pasteur to announce, "Of gases, fluids, electricity, magnetism, ozone, things known or things occult—there is nothing, in the air, conditional to life *except the germs it carries.*"

This dictum was at once fiercely attacked by the generationists who included in their party savants of European fame, the most notable being Bastian, of London. The discussion held the almost breathless attention of the newspaper-reading world, and ended some years later in Pasteur's triumphant demonstration of his thesis.

You can readily imagine that this research was not prosecuted by Pasteur because of its mere academic interest. He appended to his first paper, quoted above, this query—"What could be more desirable than to push these studies far enough to prepare the road for a series of researches into the origin of various diseases?"

In 1861 Pasteur discovered the ferment of butyric acid. In the following year he discovered the ferment of acetic acid, and showed that microbes could be distinguished into two grand classes—*aerobes* and *anaerobes.* The Academy of Sciences, which had rejected his name when offered for membership upon several previous occasions, could not longer refuse to honor a man whose fame was now world-wide. He was elected a member at the end of 1862.

The manufacturers and dealers in fermented liquors had always been subjected to annoyance and loss by their inability to make wines and beers of uniform standard and to keep them in the condition in which they were put upon the market. Alterations were constantly taking place in these articles, due, it was supposed, to certain "diseases." Inasmuch as these wares represented a large share of the wealth of France, Pasteur was urged to investigate this matter. He commenced this research in 1864.

The ensuing year, an outbreak of cholera called his attention to that disease, and he studied it with a view to finding a bacterial cause for it, but without result. In the meantime, he was investigating a pestilence of silk worms which was proving so destructive as to threaten the silk industries of southern Europe with extinction. He was quite successful with this, and was quickly able to devise a method of combating it.

Doubtless the strain incident to the many and great investigations being simultaneously pushed by him during the three years, 1865 to 1868, was responsible for a series of paralytic shocks, the first of which struck him October 10, 1868. While thought to be hopelessly ill and incapable of rational thinking, he insisted upon dictating a method of dealing with *flacherie,* a second silkworm disease which had been discovered by him in the course of his research on the silkworm pestilence. His treatment for *flacherie* proved to be a complete success, also. He recovered from this attack, but was physically lamed for the rest of his life. Although crippled in body, the work accomplished by him during his remaining twenty-seven years was not only stupendous in amount, but of transcending importance to mankind. I doubt if the example afforded by the heroic labors of the paralyzed Pasteur can be matched from the annals of all time.

By the close of 1871, he had shown that the "diseases" of wines and beers were caused by certain bacteria, all of which might be killed without injury to the product by heating it for a few minutes at a temperature of 50°–60° C.; and that if hermetically sealed at this temperature the liquors might be preserved perfectly for an indefinite period.

These studies had now thoroughly convinced their author that all diseases are of bacterial origin—a conception, you will recall, which had first come into his mind by a flash of genius ten years before. Indeed, four years prior to this (1867), Pasteur's researches had convinced a British surgeon, Joseph Lister, of Edinburgh, of the microbic origin of those purulent infections which accompany wounds and surgical operations. And although himself unacquainted with bacteriology, he successfully devised the method of asepsis which has made his name a household word.

Before the close of 1873, Pasteur finished the solution of that great problem begun at Lille nineteen years before—*the mystery of fermentation.* It is this: Certain bacteria, living at the surface of sugary fluids cause no fermentation, because they secure the oxygen which they need from the air. They are aerobic. But if sunk, by accident or otherwise, beneath the surface they must either perish or adapt themselves to their new environment by extracting oxygen from the nearest source of supply. This is the sugar of the solution. They are able to accomplish this but slowly at first, and the bulk of the first submerged bacteria suffocate. But reproducing rapidly by budding, ensuing generations are gradually but, for us, rapidly converted into true anaerobes, which, robbing the sugar molecules of oxygen, cause that chemical change called fermentation.

This problem solved, Pasteur was able to show from it the following results of his work: (1) Precisely what fermentation is, (2) that ferments are living organisms, (3) that every variety of fermentation is caused by a special ferment, (4) that neither bacteria nor any other life forms are spontaneously generated, (5) how to prepare culture media suitable to the growth of various bacteria, (6) how to propagate pure cultures of bacteria, (7) a basis of classification of bacteria, (8) the chemical and microscopical technique of bacteriology, (9) the cause and cure of various "diseases" of fermented liquors, (10) the cause and cure of various silkworm diseases, (11) an explanation of the mystery of the optical behavior of tartaric and racemic acids, (12) two new tartaric acids (13) how to synthesize meso-tartaric and racemic acids, (14) how to make racemic acid available to commerce.

In comparison with this great work of Pasteur's, the classic example of persevering genius—Newton's fourteen-year pondering over falling bodies—sinks into insignificance, no matter how considered, either as to time involved, the difficulties encountered, or the practical value of results obtained. Nor must one fail to note that incidentally Pasteur had beaten out a road into a *new world* and created two new sciences which were to serve as vehicles for its exploration and exploitation.

Pasteur's health had been so impaired by these arduous researches that he was now compelled to give up his professorship. As he was entirely without private resources, his colleagues exerted themselves upon his behalf, and succeeded in obtaining for him from the government, in 1874, an annual pension of 12,000 francs, the equivalent of the salary he had previously received.

His friends now urged him to abstain from work; but his genius could not endure inaction. He began the study of anthrax and feruncular diseases. While these studies were in progress, the bubonic plague appeared in Russia, and the yellow fever began to work havoc in the French colonies on the west coast of Africa and in the United States. Pasteur prepared a program of preliminary researches upon them. A paper to the Académie des Sciences presented December 30, 1878, closes with these words: "Is it not permissible to believe that a day will come when easily applied preventative means will arrest those scourges which suddenly desolate and terrify populations."

In 1879, he isolated the microbe of feruncles, and in 1880 those responsible for anthrax and chicken cholera. His studies had demonstrated the fact that every infectious disease thus far investigated was produced by a specific microbe; and, further, that such microbes cultivated under certain detrimental conditions become attenuated in pathogenic activity, still capable of producing a mild form of disease in an animal inoculated with them, but occasioning immunity to further attack. Such cultures of microbes of attenuated virus are *vaccines*.

Prophylactic vaccination had, of course, been known in an empirical way prior to this in connection with small-pox. But these researches of Pasteur's afforded the first explanation of that procedure, and in addition cast a flood of light upon the etiology of disease. They firmly established the germ theory, ushered in a scientific practise of medicine and sent to limbo a thousand pious superstitions about demoniacal possessions and the mysterious visitations of an all-wise Providence that doeth all things well. For these researches, the imperial government conferred upon him the cross and cordon of the Legion of Honor.

During the years of 1880, 1881, 1882, Pasteur gave his attention to hog cholera, rabies, pneumonia in cattle, the bubonic plague, yellow fever and typhoid fever. Of these six diseases he was able to carry to complete success his researches on the first three only. In 1881, a ship having come into Bordeaux from Senegal with several cases of yellow fever on board, he went thither, hoping for a favorable opportunity to study it at first hand. He was not permitted to do so. But his observations convinced him that this fever is not contagious.

Before the close of 1885, he had isolated the microbe of rabies, prepared its vaccine and perfected the method of treatment. This was a disease which caused not merely considerable property loss and suffering, it imbued the popular imagination with a dread but little less than the terror occasioned by a pestilence.

As despite the researches of hundreds of bacteriologists one may still hear it asserted that rabies is an imaginary disease, some statistics may not here be out of place. Accurate account of 320 cases of persons bitten by mad dogs prior to Pasteur's work in this field, showed a mortality of 40 per cent. The first 350 cases treated by his method furnished but one death, that of a little girl brought to the hospital in such condition and so late that Pasteur pronounced the case hopeless from the start, and only undertook it for humanity's sake. After the treatment had been given in 1,726 cases there had been but ten deaths.

The conquest of rabies was the last great work accomplished personally by Pasteur. Reattacked by paralysis in 1888, he could thenceforth prosecute his ideas only by the labor of other hands. But he had a host of disciples in Europe and America, some of whom had studied under his personal guidance, but many more who, without having seen the great master, had nevertheless lighted their torches at his flame. I know of no surer index of a man's greatness than the measure of inspiration imparted by him.

Already Gayon had proved the bacterial cause of the decay of eggs. Koch had isolated the bacilli of tuberculosis and cholera. Traube had shown the like cause of ammoniacal fermentation; and upon the knowledge thus given, Van Tieghem and Gayon had devised their well-known treatment of diseases of the urinary organs. Lister had introduced asepsis, prior to which hospital statistics showed a mortality of 68 per cent. of cases of puerperal fever, gangrene and septicæmia generally incident to surgical operations. Accounts of surgical wards of army hospitals during our own civil war, typical, of course, of all that had preceded, with their perpetual agony, suppuration and horrible odors, read like a nightmare of insanity. A noted surgeon-teacher of that day said to his students, "When an operation seems necessary, think ten times about it; for too often when we decide upon an operation we sign the patient's death warrant." Another said, "He who shall conquer purulent infection will deserve a golden statue."

But to resume our catalogue: Behring and Kitasato, investigating lock-jaw, had discovered the microbe of tetanus, and ascertained the curious fact that although the patient was constitutionally affected the microbe was localized to the wound. They further found that the systemic effect of the disease was due to a toxin produced by the bacterium which was likewise fatally affected by the toxin. So that diluted solutions of the toxin not only constituted a remedy for the disease, but also a prophylaxis when administered in advance of infection. This was the first of the series of remedies known as *anti-toxins*.

Utilizing these results in the study of diphtheria, the combined labors of Richet and Herico, Roux and Yersin, Klebs and Loeffler, eventuated in 1894 in complete mastery of this disease, whose investigation had been inaugurated by Pasteur a dozen years before. Prior to the antitoxin method of treatment, diphtheria had justly been regarded as one of the worst scourges of our race, claiming a death-toll of 60 per cent. of all cases, and frequently leaving the survivors seriously injured for the remainder of their lives. At present, the mortality is about four per cent. And vaccination with the serum rendering the recipient immune to the disease for a period of about two months, epidemics of diphtheria may be entirely prevented by utilizing this prophylactic measure.

Closely connected with these researches on tetanus and diphtheria was a remarkable research brought out about this time by Metchnikoff, one of Pasteur's Russian pupils, in which he discovered the rôle of leucophytes, or white corpuscles of the blood. It appears that they constitute, so to speak, an army of defense, attacking and "eating up" invading microbes, thus explaining, by the principle of auto-vaccination or auto-toxination, why an individual may at certain times be immune to contagious disease.

And here, permit a parenthetical word upon vivisection. This vast amount of research had entailed much experimentation with living animals; and, as might have been foreseen, certain false humanitarians raised a great outcry about it. In England this went so far as to lead to the enactment of an antivivisection law, since repealed, I believe, although organized societies there, and on the continent, and in America still carry on an agitation. However kind the surgeon or pathologist may be, he can not avoid inflicting some pain in his efforts to prevent more. Nor can it have escaped your observation that, no less than man, the lower animals profited from these discoveries which could not have been made in any other way. It is also worthy of note that no antivivisectionist has ever offered to sacrifice himself for the good of humanity. The colleagues of Pasteur testify that he always used anesthetics in his work on animals and at such times evinced the most acute sympathetic suffering; only the end in view gave him courage to go on with the experiment. He said of himself that he could never have the heart to shoot a bird for sport.

Pasteur's discoveries were epoch-making, and revealed in him the Copernicus of medicine. Prior to his researches, the causes and rational treatment of disease were no better understood than in the stone age. Naturally, his conclusions were not accepted by medical men till every possible opposition had been exhausted. Physicians resented instruction from a man devoid of medical training. "*A mere chemist*" was the sneer most frequently on the lips of his adversaries. When they could no longer deny the existence of microbes, adherents to the old school still vehemently asserted that they were merely an epiphenomenon. I recall a choleric colleague of my own in the faculty of a medical college where I was teaching twenty years ago, who in the heat of debate was wont to call out loudly—"Bring on your microbes. I'll eat a pint of any variety!" Fortunately for him no one took him at his word. The distinguished Professor Pettenkofer, of Munich, having made the same remark concerning Koch's bacillus of cholera, he was supplied with the beverage—and actually drank it. Heroic efforts of physicians enabled him to keep his soul between his teeth, and after recovery he had the manhood to publish an admission of error.

In 1880 Huxley estimated that the practical results of Pasteur's discoveries had yielded France a return in excess of the war indemnity wrested from her a decade before—one billion francs. It is safe to assert that at present they represent to the world not less than that sum annually. And how shall an estimate be made of the relief of suffering and the preservation of life?

In 1894 Pasteur's former pupil, Yersin, isolated the bacillus of the bubonic plague, and had the pleasure of exhibiting it to his old master. "There is still much to do!" said Pasteur with a sigh. His health continued to fail steadily till September 28, 1895, when a final hemorrhage quenched forever the most brilliant mind ever bestowed upon a member of the human race.

Pasteur died a poor man, although, had he so chosen, he might have aggrandized himself beyond the dreams of avarice. But, considering that his ideas were heaven-sent, he bestowed them freely upon the whole world.

I can not find more suitable words with which to close this paper than those addressed by Pasteur to the students of the University of Edinburgh in 1884 upon the occasion of his visit there for the purpose of receiving the degree of doctor of laws from that ancient foundation. "Young gentlemen, work perseveringly. Work can be made into a pleasure, and *alone* is profitable to a man, to his country, to the world. Whatever career you may embrace, look up to an exalted goal. Worship great men and great things."

CONCEALING COLORATION[1]

By ABBOTT H. THAYER

MONADNOCK, N. H.

AT the last meeting of the American Ornithologists' Union, in Washington, some forty naturalists looked in broad daylight straight at a small stuffed deer that wore from its dorsal line down its sides two white stripes in imitation of those of certain African antelopes. These stripes were in every respect such as Theodore Roosevelt says have no *concealing* virtue of any kind whatsoever.[2] Yet they so completely concealed this deer in an almost clean-shorn public park that although for each of the forty spectators I pointed straight at the deer only ten yards away, not one of them detected it. The animal was placed just above the eye-level of the spectator, exactly as African antelopes would be above that of the creeping lions or leopards. And, exactly as would commonly be the case with the antelopes, the white stripes absolutely counterfeited the glimpses of the sky-background seen through the thin half leafless bush that intervened. When the white stripes were removed the spectators exclaimed at how clearly one

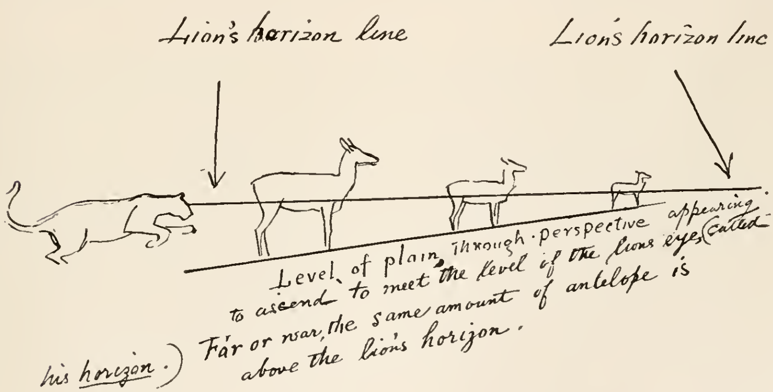
[1] These wholly unretouched illustrations absolutely demonstrate the wonderful concealing effect of the white patterns that Roosevelt and others say have no concealing effect whatsoever. These play, as Roosevelt truly asserts, little or no part when the wearer is out on the safe open plain, but seem designed for making him the very worst of targets when he tries to dodge the spring of an ambushed lion or leopard, especially at night, just as the night hawk's colors, dark and conspicuous to terrestrial eyes through all his safe aerial hunting, prove to be an unmistakable picture of his background when at last he squats on the bare rock in danger from predatory birds and mammals. No one can study these oryx head pictures without perceiving that, against the ground, the brown (of course countershaded) head is hard to distinguish, while the black-and-white one is very conspicuous. On the other hand, when the same two heads are *looked at from below, i. e.*, against the sky, it is the brown one that *shows*, and the brilliant black-and-white one that is now hard to detect. It is of this black-and-white oryx head that Roosevelt writes: "A curious instance of the lengths to which some protective-coloration theorists go is afforded by the fact that they actually treat these bold markings as obliterative or protective." Colonel Roosevelt, like the rest of the world, seems never to have thought to find out how these patterns look from a *lower level*, such as lions and leopards necessarily see from, they being under three feet tall, while the oryx and zebra are nearer five. This great oversight invalidates almost all that has ever been written on this subject.

[2] "African Game Trails," Appendix E.

could now see the deer, and all agreed that it was these white stripes that had fooled them. Dr. C. Hart Merriam said it was a most conclusive demonstration (though he still believed that such marks exist *also* for purposes of display, under other conditions).

The way this deer demonstration brings to instant ridicule the extraordinarily positive statements of Theodore Roosevelt must set the reader wondering about the value of the remainder of his attack. The simple fact is that Roosevelt, like most of the rest of the world, is totally ignorant of a great optical principle which has lain right under people's noses, and to which I have at last called attention, and which can not possibly remain ignored. All the various objections and doubts about our book, including this extraordinary tirade of Roosevelt's, have been possible *only* because of people's not seeing this principle.

The principle[3] is, basally, merely this: that if you lie on the floor you will have not the *floor* but the *ceiling* to look at, while if you were fastened to the ceiling you would see not the *ceiling* but the *floor*. All over this planet, and all over every other planet that receives light-vibrations and possesses detached objects of any sort, either on or above its surface, this law rules the aspect of every object in its appearance from the view-point of each other object. All such detached objects are for-



This diagram shows that Roosevelt is again exactly wrong when he says that to the lower-leveled eye of a wolf or cougar, a prongbuck's white rump shows *now against the sky and now below it, according to this enemy's distance.* If the antelope's rump is above the cougar's eye the same proportion of it will show against the cougar's sky at one distance as at another.

[3] Erasmus Darwin perceived this principle, but got confused in carrying it out—trying to make it explain the juxtaposition of brown backs and white bellies; the white of the bellies being, he thought, nature's attempt to match the white of the sky, for eyes beneath. Of course this *under* white can not do that, being always in shadow, and therefore practically dark brown—utterly too dark to match the over-head sky. On the other hand, white patterns on animals' *upper* slopes obey in every respect the law he foresaw, and operate upon the sight of such beholders as look from a lower level, except, of course, when the wearer is *directly over* them.

ever between the overhead light which is their *ceiling,* and the underfoot earth which is their *floor.* The higher you mount from the earth, and consequently the nearer you get to the outside of this zone of detached objects, the more do all things that you have to look at *come between you and the brown earth*—and the more these things resemble the earth in color the less you notice them. Contrariwise (let the world for the first time notice this *Contrariwise,* which would have saved Roosevelt and others so much erroneous writing), contrariwise, the nearer you get to the *bottom* of this layer of inhabitants of the atmosphere, *i. e.,* close to the earth's surface, the more you have *only* things *above* you to look at; and the more *these* things are *bright* like the sky the *less* you see them, and the darker they are the more you see them. This means that the nearer to earth's surface an animal lives, the larger will be the proportion of neighbors he detects by seeing them dark against the sky. Only such neighbors as are no taller than he will escape coming between him and his sky.

After years of trying to bring home to naturalists this great fact, which wholly suffices to account for white top-patterns in general, I know to my sorrow that nothing short of seizing them all and binding them to the ground, so that their eyes will be as low as a mouse's, will ever cause the truth to spring into vital existence for them! I have demonstrated to many audiences on both sides of the Atlantic where scarcely one man would consent actually to go down on the turf and let this immense fact rush upon his consciousness.

Everywhere, in every situation, it is the rule that animals are colored *like the background that most concerns their feeding and escaping attack.* Sea-birds, in general, are either all ocean- and sky-colored, or this with the addition of the color of the rocks they breed and roost on. Animals living between bare snow and sky are white. (I have shown by ocular demonstration the wonderful aid that this white background-matching gets from the small black marks commonly worn by these white species.) Sand-dwellers, on land or in the sea, are sand-colored. One can find pictured on a locust the peculiarities of the special type of ground he lives on, be it rock, or sand, or meadow. *Everywhere,* in every case where the animal's background is most unvarying, as in the above-cited instances, the animal's colors are at least *amply accounted for* by their matching of this background.

Now why is it that even after people *intellectually* perceive that a terrestrial mouse or lizard sees almost all sizable neighbors *against* the light, and detects them *least* when they look lightest—why is it that these people go on failing to undersand that white upper slopes on all species which need to avoid the sight of these mice and lizards are just as necessary to their wearers as is the *brownness* of the mouse or lizard, whose enemy looks at him from *above downward* and consequently sees

An imitation oryx head, looked *up* at, simulating branches against the sky—as at a reedy drinking-place it would simulate reeds.

The same oryx head and also a brown (counter-shaded) one, the former inconspicuous, the latter less so.

him *against the ground?* In each case, the animal's colors comprise all the background's typical color-notes. Under foliage, the lizard, looking *up,* sees things against a tapestry of dark twigs and the shadow-side of leaves—the whole mass *sharply patterned by bright glimpses through it of the sky above it all.* And this *ensemble* is precisely what is worn by dusky-coated white-top-striped animals that come between the lizard and this background.

What bewitchment of the student's mind thus holds him from discovering the truth that there is evidently just one universal need of *minimized visibility from the point of view which most concerns the creature looked at,* and that nature inevitably grants this minimized visibility to all creatures that can use it?

Here is the explanation of the misunderstanding. The basic use of men's brains is one which they share with the lower animals. Like all these animals, man lives, primarily, not by speculative reason, but by what for convenience we may call *mere sensation-memory.* The aborigines differ from white hunters by their still greater propensity to hunt always where they have once killed. And a horse that has once been scared by a factory whistle going off too near him on the road always afterward shows alarm when he passes that factory. Man is, we feel sure, one story higher than the other animals, and on top of what he shares with them adds a more or less vigorous layer of "reason." But let anything make the least bit of a *run* on this reason-bank, and he is bankrupt indeed, and falls back on his *sensation-memory.*

Let us examine a few of the limitations governing the vast accumulation of man's sense records. Here, for instance, is a thing seldom thought of: Man is, mainly, a *looker-down*—perhaps as much so as a cow. He tills the soil, he hunts, he fishes—largely or wholly *looking downward* in all these occupations. And the men of towns look still more predominantly *down* on desks, tables, tool-benches, etc. This habitual down-looking of men is well attested just now in New England by the difficulty the hunters for the brown-tail moth nests have in accustoming their eyes to day-long searching of the tree-tops. A few weeks of this looking *up* strains their eyes. Another proof of all this is that men say *white* is the color that shows by night. This is the idea of a race that mainly looks *downward.* A mouse, on the contrary, because almost everything comes between him and the sky, would consider *black* the color that showed best in the night. Now when some one asks us to form a clear idea of the mouse's (and the creeping lion's and leopard's) view of the animal kingdom, our thinking-power balks, and we fall back on our *sensation-memory,* which vouchsafes us, generally, not a single instance of view from this low level, while it deluges us with memories of the bird's-eye view that we habitually get of these same species. If we are forced for a moment into the realm of *thought,* in the next

The same two heads seen against sky and branches.

The same effect as in the preceding.

moment this relatively scant faculty is fatigued, and we fall back into the hands of the old animal instinct, *sensation-memory,* which we share with the horse and woodchuck, and we proceed to rattle off the list of the hundreds of times we have seen one of these white patterns, the skunk's or deer's (bright against the *ground* as man's *height* makes to be the case). But these white tops are white evidently because *concealment* from a *lower level,* for one purpose or another, is the thing most important to the animals so patterned.

Roosevelt carried into Africa the regulation *down-looker's* misconception of the subject. And nowhere on all his pages (or in fact on any other man's pages) is to be found the faintest perception that all these white patterns on zebras and antelopes were playing a *diametrically opposite* part to the eyes of the creeping enemies of these plains-haunting animals.

Colonel Roosevelt, with the best intentions, was fated to put himself on record in the most unfortunate of attacks on our book—an attack which forces us, if we answer it at all, to expose its extraordinary weaknesses. It is the nearest to one hundred per cent. of error that I have ever read, on any subject that I understood.

First, he shows fatal ignorance of the laws of optics on which the whole thing rests, and consequently absolutely misconceives what concealing-coloration *is* or *could be.* Secondly, he does not see the joke against all who try to prove that nothing has *escaped* their sight by telling what they *saw.* He would be too sagacious to apply such reasoning to practical affiairs—why does he take science less seriously? When I announce to the world the discovery of an almost universal concealing-power, *under certain conditions,* in animals' costumes, what has it to do with the case to tell of the animals one *has seen?* Let us apply Roosevelt's method to some practical case. If the police announce the discovery in the garret of some respected citizen of a complete counterfeiting apparatus, with every sign of daily use, what does it avail to testify that you have seen the citizen hundreds of times *not* counterfeiting? The discovery of the evidence compels an investigation. If the owner of a game preserve discovers in the cellar of some neighbor a supply of freshly used game traps, what does it avail that this neighbor is daily seen *not* trapping? Again only an investigation will do. What I have discovered is that all these patterns of an animal's costume *are* potential counterfeiters, of the most perfect kind, ready for action (action in some cases almost constant, in others only at rare, but vital, moments) —each one a most exquisite reproduction of *some* background typical of the wearer's habitat. An *artist* is of course the judge of such copies; and it is therefore as an expert that I pronounce on them.

No amount of reiterating that you have seen the poacher *not* poaching, or the bank-note counterfeiter not counterfeiting, or this newly

The same two heads against the sky; the black-and-white one hard to distinguish, though (as in most of these pictures) wholly uneclipsed, the brown one, though masked by many branches, very conspicuous.

The same two heads, but looked *down* at, as man commonly sees animals of lower stature than his own. The black-and-white one now *conspicuous,* the brown (of course counter-shaded) one hard to see.

discovered animals'-costume-scenery-counterfeiter *not counterfeiting* scenery, is any step at all toward finding out whether they all three do at certain times perform their tricks. Forty years of daily meeting the poacher at the post office does not strengthen his credit. And forty years of Roosevelt's seeing zebras *not* hidden by their costume, and failing to guess what the animal's stripes are for, are just as little to the point.

This *effacing machinery* is not the only highly specialized mechanism that animals *carry always with them* merely to have ready for occasional need. It is just the same with many of their other members and adaptations. The tiger's tremendous claws, if we estimate that he kills only once in two days, and that it takes perhaps four seconds for him to do it, are in operation only a 44,700-th of his life. Would Colonel Roosevelt for want of seeing them at their work decide that it was only a *theory* that they are *for* pulling down game? (I, by the way, do not even stop at the evidence that animals' costumes *are for* concealment. I point to the actual concealment in full operation.) The tiger's whole massive steely build serves him scarcely more constantly than do his claws. It, with the claws, does the pulling-down, and adds the bearing-away. The rattlesnake has a heavy rear body, growing slender and agile toward the head end, evidently in order that his terrible poison-apparatus may have a strong base to spring from. All this mechanism serves him only for occasional *instants*—days, weeks or months apart. Yet, there he always is, a heavy slow snake good only for lying in wait and for these rare murderous lunges, and totally incapable of the arboreal feats and racing of the black-snake's life. Would Roosevelt, because he so often sees rattlers *not biting,* hoot at the idea that this snake's fangs and build are made *for* biting? The generative organs of every monogamous species that breeds only once a year are carried through life for a few moments' function once a year—and so on and so forth. With costumes it is just as with all other adaptations. They may, according to their wearer's habits, play in his life a long part or a short one.

The particular herds and individuals of plains game that stood out so visible to Colonel Roosevelt were commonly those that happened to have the light behind them; and wherever any form of tree, shrub or very tall grass *constituted an element* of the scene, there were sure to be other herds and individuals in directions in which the illumination favored their counter-shading, wholly invisible amidst the haze of scrub and grass. A spectator in such a scene is surrounded with vast reaches of all-engulfing distance into which the haze of interposed scrub growth merges on every side. In these spaces a counter-shaded animal, when the direction of the daylight favors the working of his counter-shading, is already wonderfully matched to the scrub's color, and the further off he is the more of this scrub actually comes between him and the spectator. There is therefore obviously *some* distance at which he is wholly *covered* by the scrub. Now from the very nose of the beholder all the way to the point where the animal is actually hidden by accumulated twiggery there is a scale of *diminishing visibility*, and, while the light favors the animal's background-matching, he becomes utterly indistinguishable from the scrub and grass *long before* he is at the point of actual eclipse. Yet Roosevelt is able to say: "There is never any difficulty in seeing them"! Compare Stewart Edward White's description of the evanescence of deer in similar situations,[4] written before he ever heard of concealing-coloration.

It is when the light gets *behind* an animal that its main power to upset concealing coloration comes into play. Except in the middle of the day, there is always one direction which is *toward* the light, and looked at in this direction the sheltering ambiguities of these thin coverts have to give up many of their secrets. An hour earlier the antelope's imitation twig-haze passed all right, but now that the sun is low and streams through the whole gauzy growth, behold, the opaque antelope becomes a black silhouette on a light gray ground. *He* is not really a gauzy growth!

It is hardly worth while to say that all these laws of light and its relation to vegetation are practically identical the world over. Though I have been through most of Europe, from Norway and England to Italy and Sardinia, and through most of eastern North America, from Quebec to Florida, and in many of the Lesser Antilles and Trinidad (finding everywhere, what I knew before I went, that the laws of illumination of animals and vegetation are the same over the whole planet), I have *not* been in Africa. But—and this is more to the point—my critics have evidently not been in the land of the inexorable optics which govern this entire matter.

One of Roosevelt's most fundamental errors is his complete gap of perception about the effect of *motion* on concealing-coloration. In our book's introduction I say: "Thus at these crucial moments in the lives of animals, when they are on the verge of catching or being caught, sight is commonly the indispensable sense. *It is for these moments that their coloration is best adapted, and, when looked at from the point of view of enemy or prey, as the case may be, proves to be obliterative.*" Had our critics studied this sentence, it would have saved them much misapprehension of what the book is about. But here let it suffice to remind them that the tennis-player's need of bright, clean, white balls, to be seen against the green turf, entirely refutes their ideas. The tennis-player calls for clean balls when the grass-stained ones are beginning to spoil his play; and well might a hawk, if his call would avail,

[4] "The Mountains," Chapter X., On Seeing Deer.

demand a "clean chipmunk"—*i. e.*, an *un*-counter-shaded and *un*-dead-leaf-colored one—when the little beast dodges him. Note, too, that a grass-stained ball against the grass is, at its worst, far more conspicuous than an average chipmunk against the leaves, because the ball *turns over*, and therefore could not be counter-shaded. (Note also that predators in general are believed to *miss* far oftener than they succeed.)

Many familiar experiences prove this fact, that one's power to catch or hit a moving object depends on the *distinctness* with which one sees it. The more brilliantly a dodging object shows against the background, the more promptly can the brain of the pursuer command the corresponding movement. Those who have tried to catch butterflies, house-flies or mosquitoes, on the wing, or shoot a flying bird, either know this by heart or will realize it the moment they try it again. When a dark fly passes a dark space, to make sure of him you wait till he gets against a *light* space, and a shooter does the same with a bird. Throughout all nature animals' coloration proves to be such as minimizes, in the most wonderful way, to the eyes of their pursuers, their visibility *when in motion.* And in missing this fact Colonel Roosevelt has missed a vast part of the whole wonderful subject. So true is it that, as he says, motion almost ensures *detection,* that it is no wonder we find concealing-coloration by far most constantly needed and at work—making the wearer *as hard as possible to* CATCH—where there is *pursuit and flight.* This matter would come home clearly to Colonel Roosevelt if he would try to hit a concealingly counter-shaded moving target against a background that it matched, and see what kind of a score he could make compared to what he could do with an un-countershaded one.

As soon as the public have been shown the astounding concealing-power of those African animals' reed-and-sky counterfeits, such as the zebra's and oryx's—which make it as hard as possible, *by night as well as by day,* for the springing feline to distinguish between starting zebra and jostled reeds—they will begin to see how complete has been their misconception of this matter. And the moment they see a demonstration of the magical working of facsimiles of these animals amidst reeds and branches, out-of-doors, they will see at a glance *that it would be just so anywhere in the world.* Colonel Roosevelt has confounded *detection* with *catching.* There is a vast difference. Every animal that has lived a year or two has been *detected*—how many thousand times—by other animals that would gladly have caught him; yet there he still is! Detection means, in some cases, much; but in far more case it means little. As Roosevelt evidently thought about the plains game, *out in the open* detection is nothing to them. He is also right when he says that these animals, zebras for instance, are sure to be observed by the *ambushed lion* as they nervously troop down to drink. The reader shall see how wonderfully their case bears out the hypothesis that all available adaptations of an animal's body *will be found ranged against his life-and-death danger.*

Out in the open, the zebra's watchful eye and ear, backed by his agility, ensure his safety. But if he pass too near any cover as ample as the lion *must have* for his operations, his stripes begin to be a safeguard, because *cover enough to conceal the lion means reeds or branches silhouetted across the lion's view of the zebra.* The zebra is inevitably against the crouching feline's sky, and his own sky-and-reed counterfeit begins to have the advantage of confusion with the real vegetation through which the lion is *condemned* to look. A chain is no stronger than its weakest link. What is, obviously, the weakest link in the zebra's life chain? It is when he must risk *the lion's ambush and drink.* All available powers of getting through this tightest place in his life are sure to be found in operation. This *need to drink* is as much the crux of the zebra's life as the need to be able to swim would be the crux of a foot-passenger's journey from New York to California, if there were neither boats nor bridges. There will arrive in California no foot-passengers that can not swim, *because there is the Mississippi.* And there will survive no race of zebras that were not the watchfulest, the agilest and the hardest to see when they *had* to go through this greatest danger of their lives. It is their Mississippi. When a zebra comes to a drinking-place, the faintest sound that could mean an ambushed lion *must not pass undetected by him,* and he starts away from the faintest rustle. The crouching lion sees him come into the reeds—sees him all the time—and if the zebra comes within range, *springs upon him,* but even in his first spring has inevitable difficulty in distinguishing the zebra's outlines because of the absolute similarity of the zebra's imitation of reeds and sky to the real ones. The zebra's uneasiness keeps *both the real and the counterfeit in motion together.* Very often, doubtless, as the best naturalists seem to agree, the zebra's automatic *start* comes in time to save him, and the lion's instantaneous now-or-never *second spring,* such as probably all felines make, must be guided by a lightning-swift perception *which* of the violently agitated sky- and reed-stripes are the zebra and which are *not!* Any one who saw my deer at Washington will understand this (and better still will any one who will come to Monadnock and see the wonders of my artificial zebra and oryx). Plainly, then, since the zebra *must* at this necessary moment be terribly near the lion, his race could not have continued except by having every counter-balancing advantage; and it is demonstrably *here* that the full magic of his coloration comes into play. These sky-counterfeits are as plainly addressed to the lion's sight, and most of all at the night drinking-place, as the thickness of a grizzly's frontal bone is addressed to the teeth of his enemies.

Colonel Roosevelt has done himself a wrong by not studying our plates of counter-shaded "vanished" models. He does not seem to take in at all the marvelous power of this counter-shading, which can actually *efface* the thing on which it is painted. And he has an idea that it chiefly affects the lower part of an object—as if it were merely a juxtaposition of dark top to white bottom, instead of a continuous gradation over the animal's entire surface. He says: "But as a matter of fact, the great majority of these mammals, when they seek to escape observation, crouch on the ground, and in that posture the light belly escapes observation, and the animal's color pattern loses very much of, and sometimes all of, the 'full obliterative shading of surface colors' of which Mr. Thayer speaks." Let Colonel Roosevelt cover the lower half of one of our "vanished" models, in our book, and see if this cause the *upper* half to appear! Or let him cover the lower half of the *visible* monochrome model, and see if this cause the upper half to *dis*appear.

Two more particularly flagrant errors of Roosevelt's must be mentioned. First, his speaking as if an animal's *not trying to hide* disproved his being concealingly-colored. He will in time discover that in a vast majority of instances, the very reverse is the case: that the more an animal *doesn't* hide, the more nature has to help him by coloring, precisely as in the case of the zebra at the drinking-place, or the humming-bird with his head stuck into a flower, or the flamingo at dawn with his head in the mud. Second, his much-insisted-on idea that if *one* coloration is a concealer, a different one on an animal of the same general habits isn't. He might just as well apply this objection to the mixed herds of diverse-shaped African game, of which so many species have closely resemblant habits, saying, for instance: "If the zebra is built right for this life, then it is a physical impossibility that the oryx is." Or to the innumerable forest plants, each with its own shape, but with, to the casual eye, identical circumstances. Or, concerning such a company of birds as feed together on the marshes, he should say: "These curlews, plover, and sandpipers live together and eat the same things; but if the curlew's bill is the right shape for his life, the very differently shaped bills of the other species are accidents and not adaptations." This is an old, obsolete method in natural history, henceforth to be succeeded by pure experimentalism. And I am presenting simply *the experimentally established facts* of these marvelous background-matchings. Amid sunlit snow and blue shadows the blue jay *is* exquisitely 'effaced' by its most perfect matching of each color-note. Likewise the peacock up in a tree, or the wood duck among sunlit water-plants, etc.[5] Each of these *facts is here to stay,* no matter where it leads us.

[5] One of the many surprises in store for Roosevelt is the potently obliterative character of the summer dress of the male bobolink, *when seen from the hawk's viewpoint.*

Our book[6] was written only after all its facts were verified. It contains essentially nothing *but* facts, and might have been called an expert's presentation of examples of consummate resemblances between animals' costumes and certain of their backgrounds. It has greatly surprised us that so many people have so slightly noticed the *facts revealed* as to take them for illustrations of a supposed "theory." The *facts, themselves,* are what we present.

From now on I shall be delighted to show to all comers to Monadnock the perfect background-counterfeiting powers of all sorts of gorgeous birds and butterflies. I have already prepared good facsimiles of a zebra and the head of an oryx, to show the truly wonderful way in which when looked at from a creeping lion's or leopard's eye-level these animals pass for mere sky-vistas through the reeds or branches. My Washington deer was merely a crude beginning of the exhibitions that I can already give of this type of concealing-costume.

Any child who has access to a wide, open field away from lights can prove for himself that *white does not show against a starlit night sky.* And it is only fair to point out that any one so ignorant of the simplest laws of optics as to share the popular notion that it *does,* is not competent to testify in this matter. Let the experimenter hold up between his eye and a clear, moonless night sky, a white card so inclined as to permit him to see its upper side.[7] Even in a wide, open field he can at most make it come *as* bright as the sky beyond it, and consequently *vanish;* but it can not of course get *brighter* than the sky. How could it, since it owes all its light to this very sky! Yet Roosevelt says: "At night, in the darkness, . . . the white rump-mark of the antelope is almost always the first thing about them that is seen, . . . and at night it does not fade into the sky, even if the animal is on the sky-line."

Many persons who hear of the vanishing-power I show in the brilliant bird-skins and butterflies and these white-topped animals suggest that in the animals' homes all might be different. I need only answer that when they see the vast range and astounding precision of what I show, this fear will vanish. The evidence is literally overwhelming. It is in every case only against a background notably like that of the animal's home that he will vanish.

[6] "Concealing Coloration in the Animal Kingdom."

[7] Moonlight, of course, or the uneven illumination from a cloudy sky, can make white show momentarily brighter than the sky; but nature has to deal in *averages,* and these very irregularities of illumination cause the prongbuck's white just as often to look too dark as too light.

Contradicting what he says of the skunk's white, Colonel Roosevelt says: "After nightfall the zebra's stripes would be entirely invisible." Here again he is completely wrong, as if he had never hunted by night. These stripes are invisible at night *until* the enemy is near enough to endanger the zebra. Looked at as near as this, all colors *except* white, show strongly against a starlit sky.

Like John Burroughs in his *Atlantic Monthly* paper called "Gay Plumes and Dull," Colonel Roosevelt does not even take pains enough with his data. Burroughs said: "Why does only one of our four weasels turn white in winter?" The answer is that *all* of the four turn white in winter! Roosevelt says: "Bears . . . have no white on them." The fact is that seven species, without counting the two all-white kinds, wear more or less white, especially in breast-crescents, collars, and fore-shoulder stripes.

About war-paints and appendages, too, I tell only optical, invincible facts. On this subject I shall soon have more to say.

The possibility of wonderful demonstrations of the effacing-power even of stuffed skins of gorgeous or powerfully marked species such as a peacock, or an oryx or zebra, is unfolding itself to me at a rate that almost takes my breath away, and which can not fail to astonish all who witness my experiments.

Not yet understanding that this matter is unequivocally the artist's business, Colonel Roosevelt, like some of our other reviewers, proposes a "scientific" tribunal for our book. *Science* means simply *knowing.* What does science teach any scientific man more imperatively than that he must employ specialists in every direction? Does astronomy fit a man to practise medicine? Yet the astronomer and the doctor are both men of science. Do naturalists imagine that the arts can stand as they do, illuminating beacons through the ages, without having adamantine, crystal truth at their core? The laws of color-correlation are of course the very axis of the art of coloring, and any intellectual painter inevitably *is* the scientist of all that is knowable in this matter. While all painters perceive spontaneously that shadows on the snow in a sunny open field have exactly the color of the aggregate overhead sky, very few persons who are not artists can discover that they are more than "bluish." As our book's introduction explains, a colorless mirror laid in such a snow-shadow and facing upward reflects of course the overhead sky, and this reflection proves absolutely to match the snow-shadow. This knowledge of the actual color of things, and especially *of transitory aspects,* rests, then, wholly with painters; and, if *scio* means *I know,* it is *science.*

My critics say it is my *theory* that this or that bird's patterns pass for the background; yet every time I show them this bird against such a background, they either fail or nearly fail to detect it, and invariably admit that it was its patterns' resemblance to background-details that fooled them. Is it my *theory* that they are thus deceived?

Will not my critics wisely adjourn for the present the question of the validity of any *deductions* I may have made, and contemplate instead the array of actual *facts?* Whenever naturalists will take the trouble to lie down on the ground beside a stuffed flamingo, or a live one in a zoo, with horizontal sunlight bathing it, they will *see* that it looks wonderfully like a pink cloud (which is, strange to say, just what Roosevelt remarks about a flying flock of the African species), and all *discussion* as to whether this is so or not will be at an end. In connection with a long chain of similar phenomena, hitherto unknown, is this *fact* worthy only of derision? If inhabitants of the world's *floor* prove to see the more aerial species against the sky, the flamingo's aquatic enemies, dwelling *below* this floor, see denizens of the upper air *always* against the sky. The flamingo question, then, has come down to why he is colored for dawn and sunset sky more or less at the expense of his all-day matching. The answer would seem to be connected with his nocturnal habits. According to Audubon the red flamingo is nocturnal (as, apparently, all the other red and rosy waders are); and in that case his feeding wouldn't extend further into daytime than merely, at both ends of the night, to overlap into the rose and salmon light of dawn and evening. His feeding is especially unfavorable to his keeping watch against enemies, since he buries his face in the mud and muddy water in his search for the worms and other animals he lives on; and we find his coloration fitting this emergency.

This matter of sky-matching has come very clear in my demonstration with the oryx head, reproduced herein, which shows the inevitable effect of all the other branch- and sky-patterns, such as abound on birds, beasts and butterflies that are looked *up* at. I have been studying for years to find out the *exact* scene that each costume best represents; and I now beg my readers to come to Monadnock and let me show them the results.

EXPANSION OF THE USEFULNESS OF NATURAL HISTORY MUSEUMS

By Professor THOMAS H. MONTGOMERY, Jr.

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LIFE consists, to a large degree, in adjustments and responses, with institutions as well as with individuals, and the new conditions that these create must be faced in their turn. With every active growth there is branching out and so arise innumerable interlacings and entanglements of activities, one overlapping and interweaving with the next. The whole history of thought shows how subjects that once were to great extent isolated have spread out and crossed, until they compose a tangled web of endeavor, and consequently we can no longer define our sciences sharply, for each of them mingles with others on all sides. Indeed the borderlands of any science, the points where it joins with another, now make up the most interesting and promising fields of research. Thus biology at one angle passes over into medicine, at another into psychology, at another into sociology, one little corner threatens to join with mathematics, and at nearly every turn it meets with physics and chemistry. He would be a rash man who would try to-day to present a rigid classification of the sciences, they being in such a flux and flow of change; indeed they are coming more and more to constitute a unit.

But each worker has to select a particular part of this web for his study, for the reason that no man can undertake the whole; it once was that a strong mind could grasp the entire web, like as the mother spider controls all lines of her snare, but now the web is so great and complex that we single workers are like spiderlings upon it, each looking for his own particular little gnat. We single laborers associate ourselves together according to our tastes, so as to favor interchange of thoughts, thus forming societies, academies and the various other kinds of institutions, and the time has come when these different institutions should cooperate and partition out the work to be done by each, so that there may be as little waste and as little duplication as possible. For while there may be as great difficulty in characterizing institutions as in defining sciences, nevertheless mutual cooperation and division of labor have come to be a necessity.

Probably the oldest European association of naturalists was the academy, a grouping of followers around a gifted thinker. In the days of Greece such academies usually had no habitation, but the disciples followed and heard their master in the open air. In such an academy the teacher had his own doctrines most at heart, not those of others, consequently did not try to accumulate a library. Libraries arose in the orient earlier than in Europe, partly from the reverence of the eastern nations, particularly the Mohammedans, for the written word, partly from the greater age of eastern civilization; through Europe libraries arose in kingly palaces and in priestly monasteries, and these were, before the days of the printing press, the centers of book making. The foundation of distinct natural-history museums was considerably later than that of libraries for the reason that the voice of authority long took precedence over the concrete object; witness the long contention of bookly scholars over the number of legs of an insect, all disputing over various renditions of Aristotle, none condescending to catch a house fly and count its members. Alexander brought home great collections of living animals from the east, and founded therewith a zoological garden for this teacher of his, but we have few records of this collection; the beasts the Roman emperors secured were used mostly for combats in the circus, for these emperors had political and popular effects in mind and not the increase of knowledge.

The materials for the study of the natural sciences in medieval times were the libraries, museums growing up in Italy and England, and universities starting in Italy, Spain, England, France and Germany. These early universities were at first much of the type of Grecian academies, with didactic teaching; they arose from the desire of certain free spirits to gain knowledge of other kinds than that prescribed by the church. We can say that the museum was in most instances the mother of the empirical natural sciences, for it stood for the accumulation of objects of study rather than the accumulation of books. Men of inquiring mind grew up, inspired partly by curiosity, partly by superstition and belief in the black magic, who collected monstrosities and other strange specimens, without any definite idea to guide their choice; their preference was for fossils and crystals, salamanders and hedgehogs, and in general the most heterogeneous objects as one may learn from "Hudibras" or from the plates in Johnston's "Natural History." The wish was for the unusual, and specimens from foreign lands inspired much more interest than those of the native fauna and flora. The chief growth of these museums dated from the times of colonial expansion, when the ships of the Dutch and Spaniards and English brought home collections from the new and old Indies. The governments then lent their help to the museums, as an exploitation of the products of their new possessions, and the great collections of London, Paris and Amsterdam jumped in their growth and importance and have justly become objects of national pride.

The universities came to join with the museums in many cities, but have for the most part remained separate from the older of them. Perhaps the chief reason why the universities and museums have kept apart is the character of their work; natural science in a museum consists largely in accumulation of collections and in descriptive research, in the university in experimental science. This makes up the essential difference between the curator, on the one side, and the laboratory worker on the other; or, in other words, between the classifier and the experimenter. And it is curious to note that laboratories arose first quite apart from both museum and university, in the private houses of men of analytic mind; one needs only recall the names of Roger Bacon, Vesalius, Galileo, Harvey and; in modern times, Darwin. And those who were interested in comparative anatomy and physiology were at the beginning for the most part private physicians. As this work gained in importance they moved naturally to those institutions that offered the greater facilities for that kind of pursuit, consequently to the universities.

This has been the merest historical sketch of the connection of museums with other learned associations, while the subject is one of sufficient interest to fill a volume and then be far from exhausted. But it will have to suffice for our present purpose.

Now let us see the present ramifications of our institutions of natural history, and limit ourselves to the subjects of biology and geology. Of these there are, in the first place, the general academies, which may be characterized as being broad in subject, and open to all who are interested, to layman as well as to investigator. The latter quality is a particularly valuable possession, by virtue of which became associated in common interests many people who would find themselves alien in a more specialized association; for the specialist's research is largely dependent, at least in America, upon the gifts of amateurs, and all specialists are recruited from the ranks of amateurs. Probably the amateurs who are drawn to an academy by their natural tastes make better members than those who have chosen their calling after deliberation. The academies publish "proceedings" which include the most diverse subjects. Then there are museums, frequently associated with such academies, less usually with universities. Their primary object is the conservation of collections, and they have the same relation to natural history specimens as libraries have to books. The greater of them are reference collections where one goes to find the original specimens of descriptions. Their curators are men whose writing is largely limited to the materials of such collections and to the theoretical ideas based on such material. For the most part these museums now separate their reference and exhibition collections, and devote much thought to the most suitable presentation of the latter, following Huxley's thought that an exhibition collection should not aim to show all its specimens but rather to place on view particular groups of a direct teaching value. How far even the best collections do actually teach is, however, a matter of much dispute among museum directors. Some museums are trying the plan of frequently changing the exhibition collections, so as to offer more variety to the public. Thus the exhibition collections represent faunæ, factors of distribution and of evolution, phyletic series, habitats of animals, stratigraphic series, etc. For the gathering of collections of these two kinds museums, as far as they are able, send out regular collecting expeditions; and indeed our National Museum is, to a great extent, the result of natural explorations. Both academies and museums usually maintain public lecture courses—as now do almost all learned institutions.

The work that the museums are doing in biology is mainly taxonomic, the study of groups, and ecologic, that of life environments. Their teaching is accomplished by short lecture courses, natural history excursions, and by exhibition of collections illustrating particular subjects.

The remainder of the work in natural history is done mainly in other institutions. Mineralogy is the branch of geology studied chiefly in universities and various technical schools. Almost all the branches of biology, except taxonomy, are taught outside of museums. Morphology and physiology are followed mainly at universities and marine laboratories, the experimental study of evolution including inheritance at these and at special experimental stations—governmental and private, and the newer sides of biology, biochemistry, biophysics and comparative psychology are practically unrepresented at the museums. For experimental research as distinguished from taxonomic, in fact for the study of vital details of any kind, one goes to a laboratory rather than to a museum.

Thus, on the one hand, there is the natural-history museum. Its research presents the historical or phyletic standpoint, and tends to consider the entire adult organism without attempt at abstraction of particular qualities. There is the laboratory proper, at university or marine or fresh-water or experiment station, that digs into the inside of the animal with the microscope, that tries to trace its whole development, that attempts to reduce its processes to known physical and chemical factors. The two sets of institutions are, on the whole, sharply differentiated, their work is contrasted, one can not say *a priori* which has the greater importance, but in time we shall be able to decide which has brought the greatest treasures to human knowledge. Certain it is that the pioneer work of the taxonomist opened the way for the theory of descent, and that without such work the experimental student of evolution could hardly attack his subject. And high-class taxonomic work requires as rare judgment and intuition as is demanded in any other scientific pursuit.

Foremost among the institutions to-day stand the universities and the museums; all others are represented by men who have been trained in one of these two. Now what should be the attitude of them to each other, especially when they coexist, as they often do, in the same city? Mergence has been suggested, but it would appear, unwisely. For each has its honorable traditions and does not wish to surrender independence. Further, they represent such different types of work that they would accomplish much more by careful cooperation than by any blending, for coalition would produce a mongrel of less virility. The plan should be cooperation and division of labor in subjects in which they overlap, so as to avoid waste of energy, otherwise maintenance of present independence.

In these matters human knowledge and the methods of getting it are of prime importance, not the fair name of an institution; or we should state it better by saying men's labors give the name to the institution. For seen rightly a university or a museum is only a tool towards this end, and should not stand in the way of it. We often hear it said that a man is or should be an underling of a particular institution. This is radically wrong, at least provided the object of that institution is to increase knowledge and not merely to conserve it and pass it on. A university or a museum is a complex engine, but still a tool, and how it should be used should be decided by the men who know best its object, and those men are chiefly, but not wholly, the investigators —curators or professors. For a man of original ideas to subject himself to any crystallizing conditions of an institution is an anachronism and an anomaly. He serves his institution best who serves his subject most loyally. The subject is the goddess to be followed, the institution is only one of her shrines.

What we are all here for is to make the most of natural talents, and to cooperate for the good of our subjects. This can result only in benefit to the institution in whose walls we work. Applying this principle, let us see how museums may cooperate helpfully with certain other associations of naturalists.

For the most part museums fill an important place and represent activity that is not developed elsewhere. But there is some waste, and there are also opportunities that museums have not tried to grasp. For instance, little good is accomplished by public popular lectures, whether given by academy, university or museum; in my experience they appeal mostly to the mentally unoccupied, to those who lack resource in their evening hours. I would not say they are valueless, for sometimes their seed falls into proper ground, and also they eke out the salaries of poor curators and professors. But, on the whole, they are mistaken charity and so constitute a waste, unless great care is taken that there is not a plethora of them. Much attendance on lectures is like much reading of books, a poor substitute for the activities of life. Again, universities often undertake work that might be much better left to museums. Thus if there is a museum conveniently near it seems to be a waste for a university to plan large taxonomic collections or even to give courses of taxonomic nature. For if a student wishes to learn species and their distinctions, he can gain this knowledge far better in the reference museum than in the laboratory; and to change a laboratory into a museum is to injure its proper use. Taxonomic collections and courses may well be omitted from universities, and students wishing these subjects should be directed to museums. A herbarium or a collection of shells is as much out of place in a laboratory as a bull in a china shop, for the university laboratory is for experimental work.

This idea may be pushed still further. When a museum has already large reference collections, not only there is no need of universities trying to duplicate these, but also the university should leave to museums the teaching of subjects for which such collections are the basis. This is the kind of teaching that would bring most results to the museums. Thus nature-study courses of all kinds could be best presented by museums, with their large local collections and their curators trained in knowledge of species and habitudes. Systematic courses in entomology might also be most profitably given in a museum; and these are growing in importance, now that insects are receiving so much attention by agriculturalists, and by physicians in their relation to disease. Practically all of our best entomologists, mammalogists, ornithologists and systematic botanists, whose work is of the greatest practical importance, have grown up in museums. But at the present time their training consists in becoming assistants in museums, helping in the arrangements of collections with no training whatsoever in the broader sides of the subject, and taking many years to learn what they might otherwise gain in a much shorter time, provided their work was directed from the start. A man told to label a certain collection will in time learn how to do so, but if he is to do more than merely determine species he must follow a plan of work. Such a course might be worked out in some such way as the following. The curator of entomology might each year direct a course in general systematic entomology or on injurious insects. The teaching need not be done by lectures, but with specified work on the object to be carried out by the student, assigned reading and practical examinations. Not much of the curator's time need be consumed, he would simply have to outline the work and to occasionally oversee it. The student would then begin with the advantage of the help of the judgment of a trained specialist. It stands to reason that such a course under a competent entomologist could be done better in most museums than in most universities. Such an initial course might be followed by one upon some special group of insects, or by one upon insects affecting a particular industry. A student who had taken such courses could on their completion readily find a position in some other museum or in a governmental station; and surely this would prove a better method of training systematists than the present way of acting as an assistant in a museum, for the work would be definitely planned from the start. Similar courses might be offered in mammalogy, ornithology and piscology, and in geology and paleontology, for all these subjects require large collections. Forestry might also be included in part. Without doubt universities would be glad to cooperate in such work, by advising students to attend such courses, and by crediting the work towards academic degrees.

This would be a new expansion, but logically a part of the work of museums, more important than public exhibition collections and far more important than vicarious evening lectures; though these evening lectures might be rearranged so as to compose a part of the courses. How important the matter is may be seen in the fact that the U. S. National Bureau of Entomology employs some 300 men, and finds it has to train most of them for the work; they would most gladly have other institutions undertake this training. The universities are attempting to present such courses, but they are greatly handicapped by the lack of suitable collections and of systematic entomologists. A university department of biology has to give courses, and direct research work, in histology, anatomy, embryology, physiology, animal behavior, inheritance and other analytical subjects, all of laboratory nature that require apparatus and living material rather than collections; it is too much to require that they should also present the taxonomic subjects. We should not attempt in an inland university to maintain large salt-water aquaria, but go to a marine laboratory for the sea organisms; and unless there is much ground around a laboratory, we do not attempt experimental breeding in a large scale, but go to some experiment station. Equally when a subject requires large taxonomic collections we and our students should go to a museum for them, and not try to amass other collections.

Since this was written I have learned that the Chicago Academy of Sciences now presents teaching courses which receive credit from universities. This seems to me to be one of the most promising fields of expansion of the usefulness of a museum. It would bring about a serviceable cooperation with other institutions, and thereby result in economy of expenditure and effort.

The second enlargement of the museum's service is increased research. Certain museums have been most prominent in research, as the British Museum which has surpassed the universities of its land. But few others approach this museum in this respect. To my mind a museum that consists mainly of collections, and of simple caretakers of these, has a speaking resemblance to a graveyard; dead specimens and gravestones betoken the past, and a mere conservator, like a sexton, has little to add to the future. It is as sad and melancholy a state as that of a university whose professors are nothing but teachers and committee men. There were magnificent collections in Pompeii, but so long as they remained buried beneath the soil they were of absolutely no use; they became of interest only when experts examined and interpreted them. I recall well a certain museum, founded out of piety, full of dead bones, where for years the only persons of any useful activity were the janitors and mechanicians; and it had an honorable board of directors too. Museums may become stagnant quite as well as other institutions. When the preparator and mounted rhinoceros are considered above the curator, and the exhibition collection above published research, then a museum is becoming senile. The strength of an institution lies wholly in its men. Past achievements are honorable possessions, but like an old family name entail the greater responsibility on the bearer. Any one who lives in the past will be treated like the past, and drop out from the race. For what museums do we call the great ones? Those with the staffs of prominent investigators, where there are many curators and all active in research. It is just the same with universities; international reputation is not based on buildings and number of students, but upon the number of original thinkers who publish. A dictionary is a museum of words, but it has no particular use until some one comes along and uses these words for a writing that people will read.

Very frequently a museum expends a sum for a single specimen or for a collecting expedition, sufficient to maintain several good men for a year. Often again it has a chance to secure an investigator, and hesitates because the expenditure would have to be drawn from some library or janitorial fund. Too often it is apt to consider the exhibition series to be its main purpose, and to regard men valuable only as arrangers of the exhibition. The saddest trait of all is self complacence, satisfaction in conditions as they are for this marks decay.

New timber must be planted, or any institution will soon lose its prestige. Worthy collections should be housed in suitable buildings, but the crown of the whole is the strength of the staff of curators. They come first in the judgment of the world as opposed to local opinion. When one names the great museums of Paris one forgets the specimens in the revered memory of Lamarck, Cuvier, Humboldt, the Saint-Hilaires and the Milne-Edwards. Such names constitute greatness, their writings have vivified the collections. America is too young to have many great names in natural history, but what reputation would our museums have without Horn, Say, Dana, Cope, the Agassiz's, Leidy, Baird and Gray?

The whole point is to try to live up to this record of honor, if possible to surpass it. That means to recognize capable men, to keep them by freeing their time as much as possible for their researches, and to call in capable outsiders. This is the principle of President Gilman, of Johns Hopkins University, "to discover and develop such men as have unusual ability." Each particular collection should be considered the basis of work for a particular gifted man, and not be its tender. Young naturalists starting out should be helped with fellowships and advice, substantially encouraged, not treated as preparators. Museums, you surely must agree, should make places for able men, just as universities are doing, recognizing it to be a part of their duty to help the subject by helping the men. It will be costly to do this, but not if a portion of the great funds given to getting collections be given to getting men. When this is done museums in general will be great teaching institutions, and cease to be cold storage centers. It may be questioned whether it is wise policy to say one must get buildings and collections first, then we can think of men. Would it not be wiser to attempt to add men and equipment simultaneously so that the new equipment may be used to best advantage? The cart must not be put before the horse, nor the fire before the food.

For the very reason that the American spirit is so eminently utilitarian and commercial, so highly uncivilized, the learned institutions should do all in their power to help those who are working for science. If they do not offer this help, who will? All institutions should combine in this endeavor to make it possible for inquiry after knowledge to increase. They should combine in every possible way to aid the man of original ideas, for he alone is the one who advances knowledge; he is the yeast in the bread. One of the most pitiful chances we can experience is to see a man full of hunger for a scientific career, driven to an uncongenial commercial calling for the lack of opportunity and timely aid; a naturalist shudders at the thought. Such cases are frequent, and human progress is by so much the loser. Is it not a duty of society to see that men do the work for which they are naturally fitted? Yet when we examine the matter seriously, we may well doubt whether our learned institutions fully recognize this need, and whether they are doing much to realize it. It is, nevertheless, probably the greatest good that they can carry out.

THE HISTORY AND VARIETIES OF HUMAN SPEECH[1]

By Dr. EDWARD SAPIR

THE CANADIAN GEOLOGICAL SURVEY

PERHAPS no single feature so markedly sets off man from the rest of the animal world as the gift of speech, which he alone possesses. No community of normal human beings, be their advance in culture ever so slight, has yet been found, or is ever likely to be found, who do not communicate among themselves by means of a complex system of sound symbols; in other words, who do not make use of a definitely organized spoken language. It is indeed one of the paradoxes of linguistic science that some of the most complexly organized languages are spoken by so-called primitive peoples, while, on the other hand, not a few languages of relatively simple structure are found among peoples of considerable advance in culture. Relatively to the modern inhabitants of England, to cite but one instance out of an indefinitely large number, the Eskimos must be considered as rather limited in cultural development. Yet there is just as little doubt that in complexity of form the Eskimo language goes far beyond English. I wish merely to indicate that, however much we may indulge in speaking of primitive man, of a primitive language in the true sense of the word we find nowhere a trace. It is true that many of the lower animals, for example birds, communicate by means of various cries, yet no one will seriously maintain that such cries are comparable to the conventional words of present-day human speech; at best they may be compared to some of our interjections, which, however, falling outside the regular morphologic and syntactic frame of speech, are least typical of the language of human beings. We can thus safely make the absolute statement that language is typical of all human communities of to-day, and of such previous times as we have historical knowledge of, and that language, aside from reflex cries, is just as untypical of all non-human forms of animal life. Like all other forms of human activity, language must have its history.

Much has been thought and written about the history of language. Under this term may be included two more or less distinct lines of inquiry. One may either trace the changes undergone by a particular language or group of languages for as long a period as the evidence at hand allows, or one may attempt to pass beyond the limits of historically recorded or reconstructed speech, to reconstruct the ultimate

[1] Lecture delivered at the University of Pennsylvania Museum, April 1, 1911.

origin of speech in general, and to connect these remote origins by means of reconstructed lines of development with historically attested forms of speech. Superficially the latter sort of inquiry is similar in spirit to the labors of the evolutionary biologist, for in both apparently heterogeneous masses of material are, by direct chronologic testimony, inference, analogy and speculation, reduced to an orderly historical sequence. As a matter of fact, however, the reconstruction of linguistic origins and earliest lines of development is totally different in kind from biological reconstruction, as we shall see presently.

Taking up the history of language in the sense in which it was first defined, we find that there are two methods by which we can follow the gradual changes that a language has undergone. The first and most obvious method is to study the literary remains of the various periods of the language of which we have record. It will then be found that not only the vocabulary, but just as well the phonetics, word morphology, and syntactic structure of the language tend to change from one period to another. These changes are always very gradual and, within a given period of relatively short duration, slight or even imperceptible in amount. Nevertheless, the cumulative effect of these slight linguistic changes is, with the lapse of time, so great that the form of speech current at a given time, when directly compared with the form of speech of the same language current at a considerably earlier time, is found to differ from the latter much as it might from a foreign language. It is true that the rate of change has been found to be more rapid at some periods of a language than at others, but it nevertheless always remains true that the changes themselves are not violent and sudden, but gradual in character. The documentary study of language history is of course the most valuable and, on the whole, the most satisfactory. It should not be denied, however, that there are dangers in its use. Literary monuments do not always accurately reflect the language of the period; moreover, orthographic conservatism hides the phonetic changes that are constantly taking place. Thus, there is no doubt that the amount of change that English has undergone from the time of Shakespeare to the present is far greater than a comparison of present-day with Elizabethan orthography would lead the layman to suppose, so much so that I am quite convinced the great dramatist would have no little difficulty in making himself understood in Stratford-on-Avon to-day. For some languages a considerable amount of documentary historical material is available; thus, the literary monuments that enable us to study the history of the English language succeed each other in a practically uninterrupted series from the eighth century A.D. to the present time, while the course of development of Greek in its various dialects can be more or less accurately followed from the ninth century B.C., a conservative date for the Homeric poems, to the present time.

For some, in fact for most languages, however, literary monuments are either not forthcoming at all or else are restricted to a single period of short duration. At first sight it would seem that the scientific study of such languages would have to be limited to purely descriptive rather than historical data. To a considerable extent this is necessarily true, yet an intensive study will always yield at least some, oftentimes a great deal of, information of a historical character. This historical reconstruction on the basis of purely descriptive data may proceed in two ways. It is obvious that the various phonetic and grammatical features of a language at any given time are of unequal antiquity, for they are the resultants of changes that have taken place at very different periods; hence it is reasonable to suppose that internal evidence would, at least within modest limits, enable one to reconstruct the relative chronology of the language. Naturally one must proceed very cautiously in reconstructing by means of internal evidence, but it is oftentimes surprising how much the careful and methodically schooled student can accomplish in this way. Generally speaking, linguistic features that are irregular in character may be considered as relatively archaic, for they are in the nature of survivals of features at one time more widely spread. Not infrequently an inference based on internal evidence can be corroborated by direct historical testimony. One example will suffice here. We have in English a mere sprinkling of noun plurals in *-en,* such as *brethren* and *oxen.* One may surmise that nouns such as these are but the last survivals of a type formerly existing in greater abundance, and indeed a study of Old English or Anglo-Saxon demonstrates that noun plurals in *-en* were originally found in great number but were later almost entirely replaced by plurals in *-s.* There is, however, a far more powerful method of reconstructing linguistic history from descriptive data than internal evidence. This is the comparison of genetically related languages.

In making a survey of the spoken languages of the world, we soon find that though they differ from each other, they do so in quite varying degrees. In some cases the differences are not great enough to prevent the speakers of the two languages from understanding each other with a fair degree of ease, under which circumstances we are apt to speak of the two forms of speech as dialects of a single language; in other cases the two languages are not mutually intelligible, but, as in the case of English and German, present so many similarities of detail that a belief in their common origin seems warranted and indeed necessary; in still other cases the two languages are at first glance not at all similar, but reveal on a closer study so many fundamental traits in common that there seems just ground for suspecting a common origin. If other languages can be found which serve to lessen the chasm between the two, and particularly if it is possible to compare them in the form in which they existed in earlier periods, this suspicion of a common origin may be raised to a practical certainty. Thus, direct comparison of Russian and German would certainly yield enough lexical and grammatical similarities to justify one in suspecting them to have diverged from a common source; the proof of such genetic relationship, however, can not be considered quite satisfactory until the oldest forms of German speech and Germanic speech generally have been compared with the oldest forms of Slavic speech and until both of these have been further compared with other forms of speech, such as Latin and Greek, that there is reason to believe they are genetically related to. When such extensive, not infrequently difficult, comparisons have been effected, complete evidence may often be obtained of what in the first instance would have been merely suspected. If all the forms of speech that can be shown to be genetically related are taken together and carefully compared among themselves, it is obvious that much information will be inferred as to their earlier undocumented history; in favorable cases much of the hypothetical form of speech from which the available forms have diverged may be reconstructed with a considerable degree of certainty or plausibility. If under the term history of English we include not only documented but such reconstructed history as has been referred to, we can say that at least in main outline it is possible to trace the development of our language back from the present day to a period antedating at any rate 1500 B.C. It is important to note that, though the English of to-day bears only a faint resemblance to the hypothetical reconstructed Indogermanic speech of say 1500 B.C., there could never have been a moment from that time to the present when the continuity of the language was broken. From our present standpoint that bygone speech of 1500 B.C. was as much English as it was Greek or Sanskrit. The history of the modern English words *foot* and its plural *feet* will illustrate both the vast difference between the two forms of speech at either end of the series and the gradual character of the changes that have taken place within the series. Without here going into the actual evidence on which the reconstructions are based, I shall merely list the various forms which each word has had in the course of its history. Starting, then, with *foot—feet,* and gradually going back in time, we have *fūt—fīt, fōt—fēt, fōt—fḗte, fōt—fȫte, fōt—fȫti, fōt—fōti, fōt—fṓtir, fōt—fṓtiz, fōt—fṓtis, fōt—fṓtes, fōd—fṓdes,* and finally *pōd—pṓdes,* beyond which our evidence does not allow us to go; the last forms find their reflex in Sanskrit *pād—pādas.*

All languages that can be shown to be genetically related, that is, to have sprung from a common source, form a historic unit to which the term linguistic stock or linguistic family is applied. If, now, we were in a position to prove that all known forms of speech could be classified into a single linguistic stock, the apparent parallel above referred to between linguistic and biological reconstruction would be a genuine one. As it is, we must content ourselves with operating with distinct and, as far as we can tell, genetically unrelated linguistic stocks. The documentary evidence and the reconstructive evidence gained by comparison enable us to reduce the bewildering mass of known languages to a far smaller number of such larger stock groups, yet the absolute number of these latter groups still remains disquietingly large. The distribution of linguistic stocks presents great irregularities. In Europe there are only three such represented: the Indogermanic or Aryan, which embraces nearly all the better known languages of the continent; the Ural-Altaic, the best known representatives of which are Finnish, Hungarian and Turkish; and the Basque of southwestern France and northern Spain. On the other hand, that part of aboriginal North America which lies north of Mexico alone embraces fifty or more distinct linguistic stocks. Some stocks, as, for instance, the Indogermanic just referred to and the Algonkin of North America, are spread over vast areas and include many peoples or tribes of varying cultures; others, such as the Basque and many of the aboriginal stocks of California, occupy surprisingly small territories. It is possible to adopt one of two attitudes towards this phenomenon of the multiplicity of the largest known genetic speech aggregates. On the one hand one may assume that the disintegrating effects of gradual linguistic change have in many cases produced such widely differing forms of speech as to make their comparison for reconstructive purposes of no avail, in other words, that what appear to us to-day to be independent linguistic stocks appear such not because they are in fact historically unrelated, but merely because the evidence of such historical connection has been so obscured by time as to be practically lost. On the other hand, one may prefer to see in the existence of mutually independent linguistic stocks evidence of the independent beginnings and development of human speech at different times and places in the course of the remote history of mankind; there is every reason to believe that in a similar manner many religious concepts and other forms of human thought and activity found widely distributed in time and place have had multiple origins, yet more or less parallel developments. It is naturally fruitless to attempt to decide between the monogenetic and polygenetic standpoints here briefly outlined. All that a conservative student will care to do is to shrug his shoulders and to say, "Thus far we can go and no further." It should be said, however, that more intensive study of linguistic data is from time to time connecting stocks that had hitherto been looked upon as unrelated. Yet it can hardly be expected that serious research will ever succeed in reducing the present Babel to a pristine unity.

Although we can not demonstrate a genetic unity of all forms of human speech, it is interesting to observe that there are several fundamental traits that all languages have in common. Perhaps these fundamental similarities are worthy of greater attention than they generally receive and may be thought by many to possess a high degree of significance. First of all, we find that in every known language use is made of exactly the same organic apparatus for the production of speech, that is, the glottal passage in the larynx, the nasal passages, the tongue, the hard and soft palate, the teeth and the lips. The fact that we are accustomed to consider all speech as self-evidently dependent on these organs should not blind us to the importance of the association. There is, after all, no *à priori* reason why the communication of ideas should be primarily through sound symbols produced by the apparatus just defined; it is conceivable that a system of sound symbols of noises produced by the hands and feet might have been developed for the same purpose. As a matter of fact, there are many systems of thought transference or language in the widest sense of the word, as a moment's thought will show, that are independent of the use of the ordinary speech apparatus. The use of writing will occur to every one as the most striking example among ourselves. Among primitive peoples we may instance, to cite only a couple of examples of such subsidiary forms of language, the gesture language of the Plains Indians of North America and the very highly developed drum language of several African tribes. From our present point of view it is significant to note that these and other such non-spoken languages are either, as in the case of practically all systems of writing, themselves more or less dependent on a phonetic system, that is, speech in the ordinary sense of the word, or else are merely auxiliary systems intended to replace speech only under very special circumstances. The fact then remains that the primary and universal method of thought transference among human beings is *via* a special articulating set of organs. Much loose talk has been expended by certain ethnologists on the relatively important place that gesture occupies in the languages of primitive peoples, and it has even been asserted that several so-called primitive languages are unintelligible without the use of gesture. The truth, however, is doubtless that the use of gesture is associated not with primitiveness, but rather with temperament. The Russian Jew and the Italian, for instance, non-primitive as they are, make a far more liberal use of gestures accompanying speech than any of the aborigines of North America.

If we examine in a large way the structure of any given language, we find that it is further characterized by the use of a definite phonetic system, that is, the sounds made use of in its words are reducible to a limited number of consonants and vowels. It does not seem to be true, certain contradicting statements notwithstanding, that languages are to be found in which this phonetic definiteness is lacking and in which individual variation of pronunciation takes place practically without limit. It is of course freely granted that a certain amount of sound variation exists in every language, but it is important to note that such variation is always very limited in range and always takes place about a well-defined center. All known forms of speech, then, operate with a definite apparatus of sounds; statements to the contrary will in most cases be found to rest either on a faulty perception on the part of the recorder of sounds unfamiliar to his ear or on his ignorance of regular sound processes peculiar to the language. Naturally the actual phonetic systems found in various languages, however much they may resemble each other in this fundamental trait of definiteness, differ greatly in content, that is in the sounds actually employed or neglected. This is inevitable, for the vast number of possible and indeed existing speech sounds makes an unconscious selection necessary. Even so, however, it is at least noteworthy with what persistency such simple vowel sounds as *a* and *i* and such consonants as *n* and *s* occur in all parts of the world.

Even more than in their phonetic systems languages are found to differ in their morphologies or grammatical structures. Yet also in this matter of grammatical structure a survey from a broad point of view discloses the fact that there are certain deep-lying similarities, very general and even vague in character, yet significant. To begin with, we find that each language is characterized by a definite and, however complex, yet strictly delimited grammatical system. Some languages exhibit a specific type of morphology with greater clearness or consistency than others, while some teem with irregularities; yet in every case the structure tends to be of a definite and consistently carried out type, the grammatical processes employed are quite limited in number and nearly always clearly developed, and the logical categories that are selected for grammatical treatment are of a definite sort and number and expressed in a limited, however large, number of grammatical elements. In regard to the actual content of the various morphologies, we find, as already indicated, vast differences, yet here again it is important to note with what persistence certain fundamental logical categories are reflected in the grammatical systems of practically all languages. Chief among these may be considered the clear-cut distinction everywhere made between denominating and predicating terms, that is between subject and predicate, or, roughly speaking, between substantive and verb. This does not necessarily imply that we have in all cases to deal with an actual difference in phonetic form between noun and verb, though as a matter of fact such differences are generally found, but simply that the structure of the sentence is such as to show clearly that one member of it is felt by the speaker and hearer to have a purely denominating office, another a purely predicating one. It may be objected that in Chinese, for instance, there is no formal distinction made between noun and verb. True, but the logical distinction of subject and predicate is reflected in the form of the Chinese sentence, inasmuch as the subject regularly precedes the predicate; thus, while the same word *may* be either noun or verb, in any particular sentence it necessarily *is* definitely one and not the other. Other fundamental logical categories will, on a more complete survey, be found to be subject to grammatical treatment in all or nearly all languages, but this is not the place to be anything but merely suggestive. Suffice it to remark on the wide-spread systematizing of personal relations; the wide-spread development of ideas of tense, number and syntactic case relations; and the clear grammatical expression everywhere or nearly everywhere given to the largely emotional distinction of declarative, interrogative and imperative modes.

Granted that there are certain general fundamental traits of similarity in all known languages, the problem arises of how to explain these similarities. Are they to be explained historically, as survivals of features deep-rooted in an earliest form of human speech that, despite the enormous differentiation of language that the lapse of ages has wrought, have held their own to the present day, or are they to be explained psychologically as due to the existence of inherent human mental characteristics that abide regardless of time and race? If the latter standpoint be preferred, we should be dealing with a phenomenon of parallel development. It is of course impossible to decide categorically between the two explanations that have been offered, though doubtless the majority of students would incline to the psychological rather than to the historical method. At any rate, it is clear that we can not strictly infer a monogenetic theory of speech from the fundamental traits of similarity that all forms of speech exhibit. Yet even though these are of psychologic rather than historic interest, it is important to have demonstrated the existence of a common psychological substratum, or perhaps we had better say framework, which is more or less clearly evident in all languages. This very substratum or framework gives the scientific study of language a coherence and unity quite regardless of any considerations of genetic relationship of languages.

In spite of the fact that, as we have seen, no tangible evidence can be brought to bear on the ultimate origin or origins of speech, many attempts have been made, particularly in the first half of the nineteenth century, when it was more common for historical and philosophical problems of extreme difficulty to be attacked with alacrity, to point out the way in which human speech originated or at least might have originated. From the very nature of the case, these attempts could not but be deductive in method; hence, however plausible or ingenious in themselves, they have at best a merely speculative, not a genuinely scientific interest. We may therefore dispense with anything like a detailed inquiry into or criticism of these theories. Two of the most popular of them may be respectively termed the onomatopoetic or sound-imitative and the exclamatory theories. According to the former, the first words of speech were onomatopoetic in character, that is, attempts to imitate by the medium of the human organs of speech, the various cries and noises of the animate and inanimate world. Thus, the idea of a "hawk" would come to be expressed by an imitative vocable based on the actual screech of that bird; the idea of a "rock" might be expressed by a combination of sounds intended in a crude way to reproduce the noise of a rock tumbling down hill or of a rock striking against the butt of a tree; and so on indefinitely. In course of time, as these imitative words by repeated use became more definitely fixed in phonetic form, they would tend to take on more and more the character of conventional sound-symbols, that is of words, properly speaking. The gradual phonetic modifications brought on in the further course of time would finally cause them to lose their original onomatopoetic form. It may be freely granted that many words, particularly certain nouns and verbs having reference to auditory phenomena, may have originated in this way; indeed, many languages, among them English, have at various times, up to and including the present, made use of such onomatopoetic words. It is difficult, however, to see how the great mass of a vocabulary, let alone a complex system of morphology and syntax, could have arisen from an onomatopoetic source alone. The very fact that onomatopoetic words of relatively recent origin are found here and there in sharp contrast to the overwhelmingly larger non-onomatopoetic portion of the language accentuates, if anything, the difficulty of a general explanation of linguistic origins by means of the onomatopoetic theory.

The exclamatory theory, as its name implies, would find the earliest form of speech in reflex cries of an emotional character. These also, like the hypothetical earliest words of imitative origin, would in course of time become conventionalized and sooner or later so modified in phonetic form as no longer to betray their exclamatory origin. The criticisms urged against the onomatopoetic theory apply with perhaps even greater force to the exclamatory one. It is, if anything, even more difficult here than in the former case to see how a small vocabulary founded on reflex cries could develop into such complex linguistic systems as we have actually to deal with. It is further significant that hardly anywhere, if at all, do the interjections play any but an inconsiderable, almost negligible, part in the lexical or grammatical machinery of language. An appeal to the languages of primitive peoples in order to find in them support for either of the two theories referred to is of little or no avail. Aside from the fact that their elaborateness of structure often seriously militates against our accepting them as evidence for primitive conditions, we do not on the whole find either the onomatopoetic or exclamatory elements of relatively greater importance in them than elsewhere. Indeed the layman would be often surprised, not to say disappointed, at the almost total absence of onomatopoetic traits in many American Indian languages, for instance. In Chinook and related dialects of the lower course of the Columbia, onomatopoesis is developed to a more than usual extent, yet, as though to emphasize our contention with an apparent paradox, hardly anywhere is the grammatical mechanism of a subtler, anything but primitive character. We are forced to conclude that the existence of onomatopoetic and exclamatory features is as little correlated with relative primitiveness as we have found the use of gesture to be. As with the two theories of origin we have thus briefly examined, so it will be found to be with other theories that have been suggested. They can not, any of them, derive support from the use of the argument of survivals in historically known languages; they all reduce themselves to merely speculative doctrines.

So much for general considerations on language history. Returning to the gradual process of change which has been seen to be characteristic of all speech, we may ask ourselves what is the most central or basic factor in this never-ceasing flux. Undoubtedly the answer must be: phonetic change or, to put it somewhat more concretely, minute or at any rate relatively trivial changes in pronunciation of vowels and consonants which, having crept in somehow or other, assert themselves more and more and end by replacing the older pronunciation, which becomes old-fashioned and finally extinct. In a general way we can understand why changes in pronunciation should take place in the course of time by a brief consideration of the process of language learning. Roughly speaking, we learn to speak our mother-tongue by imitating the daily speech of those who surround us in our childhood. On second thoughts, however, it will be seen that the process involved is not one of direct imitation, but of indirect imitation based on inference. Any given word is pronounced by a succession of various more or less complicated adjustments of the speech organs. These adjustments or articulations give rise to definite acoustic effects, effects which, in their totality, constitute speech. Obviously, if the child's imitative efforts were direct, it would have to copy as closely as possible the speech articulations which are the direct source of what it hears. But it is still more obvious that these speech articulations are largely beyond the power of observation and hence imitation. It follows that the actual sounds, not the articulations producing them, are imitated. This means that the child is subject to a very considerable period of random and, of course, wholly involuntary experimenting in the production of such articulations as would tend to produce sounds or combinations of sounds approximating more or less closely those the child hears. In the course of this experimenting many failures are produced, many partial successes. The articulations producing the former, inasmuch as they do not give results that match the sounds which it was intended to imitate, have little or no associative power with these sounds, hence do not readily form into habits; on the other hand, articulations that produce successes or comparative successes will naturally tend to become habitual. It is easy to see that the indirect manner in which speech articulations are acquired necessitates an element of error, very slight, it may be, but error nevertheless. The habitual articulations that have established themselves in the speech of the child will yield auditory results that approximate so closely to those used in speech by its elders, that no need for correction will be felt. And yet it is inevitable that the sounds, at least some of the sounds, actually pronounced by the child will differ to a minute extent from the corresponding sounds pronounced by these elders. Inasmuch as every word is composed of a definite number of sounds and as, furthermore, the language makes use of only a limited number of sounds, it follows that corresponding to every sound of the language a definite articulation will have become habitual in the speech of the child; it follows immediately that the slight phonetic modifications which the child has introduced into the words it uses are consistent and regular. Thus if a vowel *a* has assumed a slightly different acoustic shade in one word, it will have assumed the same shade in all other cases involving the old *a*-vowel used by its elders, at any rate in all other cases in which the old *a*-vowel appears under parallel phonetic circumstances.

Here at the very outset we have illustrated in the individual the regularity of what have come to be called phonetic laws. The term "phonetic *law*" is justified in so far as a common tendency is to be discovered in a large number of individual sound changes. It is important, however, to understand that phonetic law is a purely historic concept, not one comparable to the laws of natural science. The latter may be said to operate regardless of particular times and places, while a phonetic law is merely a generalized statement of a process that took place in a restricted area within a definite period of time. The real difficulty in the understanding of phonetic change in language lies not in the fact of change itself, nor in the regularity with which such change proceeds in all cases affected, but, above all, in the fact that phonetic changes are not merely individual, but social phenomena; in other words, that the speech of all the members of a community in a given time and place undergoes certain regular phonetic changes. Without here attempting to go into the details of this process of the transformation of an individual phonetic peculiarity into a social one, we will doubtless not be far wrong in assuming that uniformity is at first brought about by a process of unconscious imitation, mutual to some extent, among the younger speakers of a restricted locality, later, perhaps, by the half-conscious adoption of the new speech peculiarity by speakers of neighboring localities, until, finally, it has spread either over the entire area in which the language is spoken or over some definite portion of it. In the former case the historic continuity of the language as a unit is preserved, in the latter a dialectic peculiarity has asserted itself. In the course of time other phonetic peculiarities spread that serve to accentuate the dialectic division. However, the ranges of operation of the different phonetic laws need not be coterminous, so that a network of dialectic groupings may develop. At least some of the dialects will diverge phonetically more and more, until in the end forms of speech will have developed that deserve to be called distinct languages. It can not be denied that, particularly after a considerable degree of divergence has been attained, other than purely phonetic characteristics develop to accentuate a difference of dialect, but every linguistic student is aware of the fact that the most easily formulated and, on the whole, the most characteristic differences between dialects and between languages of the same genetic group are phonetic in character.

True, some one will say, changes of a purely phonetic character can be shown to be of importance in the history of language, but what of changes of a grammatical sort? Are they not of equal or even greater importance? Strange as it may seem at first blush, it can be demonstrated that many, perhaps most, changes in grammatical form are at last analysis due to the operation of phonetic laws. Inasmuch as these phonetic laws affect the phonetic form of grammatical elements as well as of other linguistic material, it follows that such elements may get to have a new bearing, as it were, brought about by their change in actual phonetic content; in certain cases, what was originally a single grammatical element may in this way come to have two distinct forms, in other cases two originally distinct grammatical elements may come to have the same phonetic appearance, so that if circumstances are favorable, the way is paved for confusion and readjustment. Briefly stated, phonetic change may and often does necessitate a readjustment of morphologic groupings. It will be well to give an example or two from the history of the English language. In another connection we have had occasion to briefly review the history of the words *foot* and *feet*. We saw that there was a time when these words had respectively the form *fōt* and *fōti*. The final *i*-vowel of the second word colored, by a process of assimilation which is generally referred to as "umlaut," the *ō* of the first syllable and made it *ö*, later unrounded to *ē*; the final *i,* after being dulled to an *e,* finally dropped off altogether. The form *fōti* thus step by step developed into the later *fēt,* which is the normal Anglo-Saxon form. Note the result. In *fōti* and other words of its type the plural is expressed by a distinct suffix *-i,* in *fēt,* as in modern English *feet,* and in words of corresponding form it is expressed by an internal change of vowel. Thus an entirely new grammatical feature in English, as also in quite parallel fashion in German, was brought about by a series of purely phonetic changes, in themselves of no grammatical significance whatever.

Such grammatical developments on the basis of phonetic changes have occurred with great frequency in the history of language. In the long run, not only may in this way old grammatical features be lost and new ones evolved, but the entire morphologic type of the language may undergo profound modification. A striking example is furnished again by the history of the English language. It is a well-known feature of English that absolutely the same word, phonetically speaking, may often, according to its syntactic employment, be construed as verb or as noun. Thus we not only *love* and *kiss,* but we also give our *love* or a *kiss,* that is, the words *love* and *kiss* may be indifferently used to predicate or to denominate an activity. There are so many examples in English of the formal, though not syntactic, identity of noun stem and verb stem that it may well be said that the English language is on the way to become of a purely analytic or isolating type, more or less similar to that of Chinese. And yet the typical Indogermanic language of earlier times, as represented say by Latin or Greek, always makes a rigidly formal, not merely syntactic, distinction between these fundamental parts of speech. If we examine the history of this truly significant change of type in English, we shall find that it has been due at last analysis to the operation of merely phonetic laws. The original Anglo-Saxon form of the infinitive of the verb *kiss* was *cyssan,* while the Anglo-Saxon form of the noun *kiss* was *cyss.* The forms in early middle English times became dulled to *kissen* and *kiss,* respectively. Final unaccented *-n* later regularly dropped off, so that the infinitive of the verb came to be *kisse.* In Chaucer's day the verb and the noun were still kept apart as *kisse* and *kiss,* respectively; later on, as a final unaccented *-e* regularly dropped off, *kisse* became *kiss,* so that there ceased to be any formal difference between the verb and noun. The history of the Anglo-Saxon verb *lufian* "to love" and noun *lufu* "love" has been quite parallel; the two finally became confused in a single form *luv,* modern English *love.* Once the pace has been set, so to speak, for an interchange in English between verbal and nominal use of the same word, the process, by the working of simple analogy, is made to apply also to cases where in origin we have to deal with only one part of speech; thus we may not only have a sick *stomach,* but we may *stomach* an injury (noun becomes verb), and conversely we may not only *write up* a person, but he may get a *write up* (verb becomes noun). It has, I hope, become quite clear by this time how the trivial changes of pronunciation that are necessitated by the very process of speech acquirement may, in due course of time, profoundly change the fundamental characteristics of language. So also, if I may be pardoned the use of a simile, may the slow erosive action of water, continued through weary ages, profoundly transform the character of a landscape. If there is one point of historic method rather than another that the scientific study of language may teach other historical sciences, it is that changes of the greatest magnitude may often be traced to phenomena or processes of a minimal magnitude.

On the whole, phonetic change may be said to be a destructive or at best transforming force in the history of language. Reference has already been made to the influence of analogy, which may, on the contrary, be considered a preservative and creative force. In every language the existing morphological groups establish more or less definite paths of analogy to which all or practically all the lexical material is subjected; thus a recently acquired verb like *to telegraph* in English is handled in strict analogy to the great mass of old verbs with their varying forms. Such forms as *he walks* and *he laughs* set the precedent for *he telegraphs,* forms like *walking* and *laughing* for *telegraphing.* Without such clear-cut grooves of analogy, indeed, it would be impossible to learn to speak, a corollary of which is that there is a limit to the extent of grammatical irregularity in any language. When, for some reason or other, as by the disintegrating action of phonetic laws, too great irregularity manifests itself in the morphology of the language, the force of analogy may assert itself to establish comparative regularity, that is, forms which belong to ill-defined or sparsely represented morphologic groups may be replaced by equivalent forms that follow the analogy of better-defined or more numerously represented groups. In this way all the noun plurals of English, if we except a few survivals like *feet* and *oxen,* have come to be characterized by a suffixed *-s;* the analogical power of the old *-s* plurals was strong enough to transform all other plurals, of which Anglo-Saxon possessed several distinct types. The great power exerted by analogy is seen in the persistence with which children, whose minds are naturally unbiased by tradition, use such forms as *foots* and *he swimmed.* Let us not smile too condescendingly at the use of such forms; it may not be going too far to say that there is hardly a word, form, or sound in present-day English which was not at its first appearance looked upon as incorrect.

The disintegrating influence of phonetic change and the leveling influence of analogy are perhaps the two main forces that make for linguistic change. The various influences, however, that one language may exert upon another, generally summed up in the word borrowing, are also apt to be of importance. As a rule such influence is limited to the taking over or borrowing of certain words of one language by another, the phonetic form of the foreign word almost always adapting itself to the phonetic system of the borrowing language. Besides this very obvious sort of influence, there are more subtle ways in which one language may influence another. It is a very noteworthy phenomenon that the languages of a continuous area, even if genetically unrelated and however much they may differ among themselves from the point of view of morphology, tend to have similar phonetic systems or, at any rate, tend to possess certain distinctive phonetic traits in common. It can not be accidental, for instance, that both the Slavic languages and some of the neighboring but absolutely unrelated Ural-Altaic languages (such as the Cheremiss of the Volga region) have in common a peculiar dull vowel, known in Russian as *yerí,* and also a set of palatalized or so-called "soft" consonants alongside a parallel set of unpalatalized or so-called "hard" consonants. Similarly, we find that Chinese and Siamese have in common with the unrelated Annamite and certain other languages of Farther India a system of musical accent. A third very striking example is afforded by a large number of American Indian linguistic stocks reaching along the Pacific coast from southern Alaska well into California and beyond, which have in common peculiar voiceless *l*-sounds and a set of so-called "fortis" consonants with cracked acoustic effect. It is obvious that in all these cases of comparatively uniform phonetic areas embracing at the same time diverse linguistic stocks and types of morphology we must be dealing with some sort of phonetic influence that one language may exert upon another. It may also be shown, though perhaps less frequently, that some of the morphologic traits of one language may be adopted by a neighboring, sometimes quite unrelated, language, or that certain fundamental grammatical features are spread among several unrelated linguistic stocks of a continuous area. One example of this sort of influence will serve for many. The French express the numbers 70, 80 and 90, respectively, by terms meaning 60-10, 4 twenties and 4 twenties 10; these numerals, to which there is no analogy in Latin, have been plausibly explained as survivals of a vigesimal method of counting, that is counting by twenties, the numbers above 20, a method that would seem to have been borrowed from Gallic, a Celtic language, and which still survives in Gaelic and other modern Celtic languages. This example is the more striking as the actual lexical influence which Celtic has exerted upon French is surprisingly small. So much for the influence of borrowing on the history of a language.

We may turn now to take up the matter of the varieties of human speech. One method of classifying the languages of the world has been already referred to; it may be termed the genetic method, inasmuch as it employs as its criterion of classification the demonstrable relation of certain languages as divergent forms of some older form of speech. As we have already seen, the linguistic stocks which we thus get as our largest units of speech are too numerous to serve as the simplest possible reduction of the linguistic material to be classified. One naturally turns, therefore, to a psychological classification, one in which the classificatory criterion is the fundamental morphological type to which a particular language or stock is to be assigned. Such a classification of morphological types may proceed from different points of view, varying emphasis being laid on this or that feature of morphology. It is clear at the outset that we have to distinguish between what we may call the subject-matter or content of morphology and the mere form pure and simple. Any grammatical system gives formal expression to certain modes or categories of thought, but the manner of expression of these categories or the formal method employed may vary greatly both for different categories and for different languages. Not infrequently the same logical category may be expressed by different formal methods in the same language. Thus, in English, the negative idea is expressed by means of three distinct formal methods exemplified by *untruthful,* with its use of a prefix *un-,* which can not occur as a freely movable word; *hopeless,* with its use of a suffix *-less,* which again can not occur as a freely movable word; and *not good,* in which the negative idea is expressed by an element (*not*) that has enough mobility to justify its being considered an independent word. We have here, then, three formal processes illustrated to which may be assigned the terms prefixing, suffixing and juxtaposing in definite order. While the same logical category may be grammatically expressed by different formal methods, it is even more evident that the same general formal method may be utilized for many different categories of thought. Thus, in English, the words *books* and *worked* use the same method of suffixing grammatical elements, the one to express the concept of plurality, the other that of past activity. The words *feet* and *swam,* furthermore, respectively express the same two concepts by the use of an entirely distinct formal method, that of internal vowel change.

On the whole one finds that it is possible to distinguish between two groups of grammatically expressed logical categories. One group may be characterized as derivational; it embraces a range of concepts expressed by grammatical elements that serve to limit or modify the signification of the word subjected to grammatical treatment without seriously affecting its relation to other words in the sentence. Such merely derivational elements are, in English, prefixes like *un-,* suffixes like *-less,* agentive suffixes like *-er* in *baker,* and numerous others. The second group of logical concepts and corresponding grammatical elements may be characterized as relational; they not merely serve to give the word affected a new increment of meaning, as is the case with the first group, but also assign it a definite syntactic place in the sentence, defining as they do its relation to other words of the sentence. Such a relational grammatical element, in English, is the plural *-s* suffix; a word, for instance, like *books* differs from its corresponding singular *book* not merely in the idea of plurality conveyed by the suffix *-s,* but assumes a different grammatical relation to other words in the sentence —a book *is,* but books *are.* Such relational elements are, furthermore, the case and gender suffixes of nouns and adjectives in Indogermanic languages; furthermore, the personal endings and tense suffixes of verbs. On the whole it may be said that derivational elements are of relatively more concrete signification than the relational ones and tend to become more thoroughly welded into a word unit with the basic word or stem to which they are attached or which they affect. This statement, however, is only approximately of general application and is subject to numerous qualifications. The greatest degree of concreteness of meaning conveyed by derivational elements is probably attained in many, though by no means all, American Indian languages, where ideas of largely material content are apt to be expressed by grammatical means. To this tendency the name of polysynthesis has been applied. Thus in Yana, an Indian language of northern California, such ideas as up a hill, across a creek, in the fire, to the east, from the south, immediately, in vain and a host of others are expressed by means of grammatical suffixes appended to the verb stem; so also in Nootka, an Indian language of Vancouver Island, so highly special ideas as on the head, in the hand, on the rocks, on the surface of the water, and many others, are similarly expressed as suffixes. It is important to note that, although the distinction between derivational and relational grammatical elements we have made is clearly reflected in some way or other in most languages, they differ a great deal as to what particular logical concepts are treated as respectively derivational or relational. Such concepts as those of sex gender, number and tense, which in Indogermanic are expressed as relational elements, are in other linguistic stocks hardly to be separated, as regards their grammatical treatment, from concepts treated in a clearly derivational manner. On the other hand, demonstrative ideas, which in most Indogermanic languages receive no relational syntactic treatment, may, as in the Kwakiutl language of British Columbia, serve an important relational function, analogous, say, to the Indogermanic use of gender; just as in Latin, for instance, such a sentence as "I saw the big house" is expressed by "I-saw house-masculine-objective big-masculine-objective," with a necessary double reference to the concepts of case relation and gender, so in Kwakiutl the sentence "I saw the house" would have to be expressed by some such sentence as "I-saw-the-objective-near-you house-visible-near-you," with an analogous necessary double reference to the demonstrative relations involved. If, now, it has been shown that no necessary correlation exists between particular logical concepts and the formal method of their grammatical rendering, and if, furthermore, there can not even be shown to be a hard and fast line in grammatical treatment between concepts of a derivational and concepts of a more definitely relational character, what becomes of the logical category *per se* as a criterion of linguistic classification on the basis of form? Evidently it fails us. Of however great psychological interest it might be to map out the distribution in various linguistic stocks of logical concepts receiving formal treatment, it is clear that no satisfactory formal classification of linguistic types would result from such a mapping.

Having thus disposed of the subject-matter of linguistic morphology as a classificatory criterion, there is left to us the form pure and simple. Here we are confronted first of all by a number of formal grammatical methods or processes. These, being less numerous than the logical categories which they express themselves, and, furthermore, being on the whole more easily defined and recognized, would seem to lend themselves more easily to classificatory purposes. The simplest grammatical process is the *juxtaposing of words in a definite order,* a method made use of to perhaps the greatest extent by Chinese, to a very large extent also by English; the possibilities of the process from the point of view of grammatical effectiveness may be illustrated by comparing such an English sentence as "The man killed the bear" with "The bear killed the man," the actual words and forms being identical in the two sentences, yet definite case relations being clearly expressed in both. A somewhat similar process, yet easily enough kept apart, is *compounding,* that is, the fusion of two words or independent stems, into a firm word-unit; the process is particularly well developed in English, as illustrated by words like *railroad* and *underestimate,* and indeed is found widely spread among the most diverse linguistic stocks. In some languages, as in the Sioux and Paiute of our own country, compounding of verb stems is frequent, as illustrated by such forms as *to eat-stand,* that is *to eat while standing;* on the other hand, in not a few linguistic stocks, as the wide-spread Athabascan stock of North America and the Semitic languages, compounding as a regular process is almost or entirely lacking. Perhaps the most commonly used formal method of all is *affixing,* that is, the appending of grammatical elements to a word or to the body or stem of a word; the two most common varieties of affixing are prefixing and suffixing, examples of which have been already given from English. Probably the majority of linguistic stocks make use of both prefixes and suffixes, though they differ greatly as to the relative importance to be attached to these two classes of elements. Thus, while both in Indogermanic and in the Bantu languages of Africa prefixes and suffixes are to be found, we must note that the greater part of the grammatical machinery of Indogermanic is carried on by its suffixes, while it is the prefixes that in Bantu take the lion's share of grammatical work. There are also not a few linguistic stocks in which suffixing as a process is greatly developed, while prefixing is entirely unknown; such are Ural-Altaic, Eskimo, and the Kwakiutl and Nootka languages of British Columbia. On the other hand, languages in which prefixes are used, but no suffixes, seem to be quite rare. A third variety of affixing, known as infixing, consists in inserting a grammatical element into the very body of a stem; though not nearly so wide-spread as either prefixing or suffixing, it is a well-attested linguistic device in Malayan, Siouan, and elsewhere. Still another wide-spread grammatical process is *reduplication,* that is, the repetition of the whole or, generally, only part of the stem of a word; in Indogermanic we are familiar with this process in the formation, for instance, of the Greek perfect, while in many American Indian languages, though in far from all, the process is used to denote repeated activity. Of a more subtle character than the grammatical processes briefly reviewed thus far is *internal vowel* or *consonant change.* The former of these has been already exemplified by the English words *feet* and *swam* as contrasted with *foot* and *swim;* it attains perhaps its greatest degree of development in the Semitic languages. The latter, internal consonant change, is on the whole a somewhat rare phenomenon, yet finds an illustration in English in at least one group of cases. Beside such nouns as *house, mouse,* and *teeth* we have derived verbs such as *to house, mouse around,* and *teeth;* in other words a certain class of verbs is derived from corresponding nouns by the changing of the final voiceless consonants of the latter to the corresponding voiced consonants. In several non-Indogermanic linguistic stocks, as in Takelma of southwestern Oregon and in Fulbe of the Soudan, such grammatical consonant changes play a very important part. As the last formal grammatical process of importance may be mentioned *accent,* and here we have to distinguish between stress accent and musical or pitch accent. An excellent example of the grammatical use of stress accent is afforded in English by such pairs of words as *cónflict* and *conflíct, óbject* and *objéct,* the verb being accented on the second syllable, the noun on the first. Musical accent is a far more prevalent phonetic characteristic than is perhaps generally supposed; it is by no means confined to Chinese and neighboring languages of eastern Asia, but is found just as well in many languages of Africa and, as has been recently discovered by Mr. J. P. Harrington and the writer, in a few North American Indian languages. As a process of definite grammatical significance, however, musical accent is not so wide-spread. It is found, to give but one example, in the earlier stages of Indogermanic, as exemplified, among others, by classical Greek and by Lithuanian.

Having thus briefly reviewed the various grammatical processes used by different languages, we may ask ourselves whether the mapping out of the distribution of these processes would be of more service to us in our quest of the main types of language than we have found the grammatical treatment of logical concepts to be. Here a difficulty presents itself. If each linguistic stock were characterized by the use of just one or almost entirely one formal process, it would not be difficult to classify all languages rather satisfactorily on the basis of form. But there are great differences in this respect. A minority of linguistic stocks content themselves with a consistent and thoroughgoing use of one process, as does Eskimo with its suffixing of grammatical elements, but by far the larger number make use of so many that their classification becomes difficult, not to say arbitrary. Thus in Greek alone every one of the processes named above, excepting consonant change, can be exemplified. Even if we limit ourselves to a consideration of grammatical processes employed to express the relational concepts, we shall find the same difficulty, for the same language not infrequently makes use of several distinct processes for concepts of this class.

On a closer study of linguistic morphology, however, we find that it is possible to look at the matter of form in language from a different, at the same time more generalized, point of view than from that of the formal processes employed themselves. This new point of view has regard to the inner coherence of the words produced by the operation of the various grammatical processes, in other words, to the relative degree of unity which the stem or unmodified word plus its various grammatical increments or modifications possesses, emphasis being particularly laid on the degree of unity which the grammatical processes bring about between the stem and the increments which express relational concepts. On the basis of this formal criterion we may classify languages, at least for the purposes of this paper, into the three main types of linguistic morphology generally recognized. The first type is characterized by the use of words which allow of no grammatical modification whatever, in other words the so-called *isolating* type. In a language of this type all relational concepts are expressed by means of the one simple device of juxtaposing words in a definite order, the words themselves remaining unchangeable units that, according to their position in the sentence, receive various relational values. The classical example of such a language is Chinese, an illustration from which will serve as an example of the isolating type of sentence. *wōo̯*^{3} (rising from deep tone) *pū*^{2} (rising from high) *p‘ā*^{4} (sinking from middle) *t‘ā*^{1} (high) may be literally translated "I not fear he," meaning "I do not fear him"; *wōo̯*^{3} "I" as subject comes first; *p‘ā*^{4} "fear" as predicate follows it; *pū*^{2} "not," inasmuch as it limits the range of meaning given by the predicate, must precede it, hence stands between the subject and predicate; finally *t‘ā*^{2} "he" as object follows the predicate. If we exchange the positions of *wōo̯*^{3} and *t‘ā*^{1} we change their syntactical bearing; *wōo̯*^{3} "I" becomes "me" as object, while *t‘ā*^{1}, which in our first sentence was best translated as "him" now becomes "he" as subject, and the sentence now takes on the meaning of "he does not fear me."

In the second main type of language, generally known as the *agglutinative,* the words are not generally unanalyzable entities, as in Chinese, but consist of a stem or radical portion and one or more grammatical elements which partly modify its primary signification, partly define its relation to other words in the sentence. While these grammatical elements are in no sense independent words or capable of being understood apart from their proper use as subordinate parts of a whole, they have, as a rule, their definite signification and are used with quasi-mechanical regularity whenever it is considered grammatically necessary to express the corresponding logical concept; the result is that the word, though a unit, is a clearly segmented one comparable to a mosaic. An example taken from Turkish, a typical agglutinative language, will give some idea of the spirit of the type it represents. The English sentence "They were converted into the (true) faith with heart and soul" is rendered in Turkish *džan u gönül-den iman-a gel-ir-ler*[2] literally translated, "Heart and soul-from belief-to come-ing-plural." The case-ending *-den* "from" is here appended only to *gönül* "soul" and not to *džan* "heart," though it applies equally to both; here we see quite clearly that a case-ending is not indissolubly connected with the noun to which it is appended, but has a considerable degree of mobility and corresponding transparency of meaning. The verb form *gel-ir-ler,* which may be roughly translated as "they come," is also instructive from our present point of view; the ending *-ler* or *-lar* is quite mechanically used to indicate the concept of plurality, whether in noun or verb, so that a verb form "they come," really "come-plural," is to some extent parallel to a noun form like "books," really "book-plural." Here we see clearly the mechanical regularity with which a logical concept and its corresponding grammatical element are associated.

In the third, the *inflective,* type of language, while a word may be analyzed into a radical portion and a number of subordinate gram-

[2] The Turkish and Chinese examples are taken from F. N. Fisk's "Die Haupttypen des Sprachbaus."

matical elements, it is to be noted that the unity formed by the two is a very firm one, moreover that there is by no means a mechanical one-to-one correspondence between concept and grammatical element. An example from Latin, a typical inflective language, will illustrate the difference between the agglutinative and inflective types. In a sentence like *videō hominēs* "I see the men," it is true that the verb form *videō* may be analyzed into a radical portion *vide-* and a personal ending *-ō,* also that the noun form *hominēs* may be analyzed into a radical portion *homin-* and an ending *-ēs* which combines the concepts of plurality with objectivity, that is, a concept of number with one of case. But, and here comes the significant point, these words, when stripped of their endings, cease to have even a semblance of meaning, in other words, the endings are not merely agglutinated on to fully-formed words, but form firm word-units with the stems to which they are attached; the absolute or rather subjective form *homō,* "man," is quite distinct from the stem *homin-* which we have obtained by analysis. Moreover, it should be noted that the ending *-ō* is not mechanically associated with the concept of subjectivity of the first person singular, as is evidenced by such forms as *vīdī* "I saw" and *videam* "I may see"; in the ending *-ēs* of *hominēs* the lack of the mechanical association I have spoken of is even more pronounced, for not only are there in Latin many other noun endings which perform the same function, but the ending does not even express a single concept, but, as we have seen, a combined one.

The term *polysynthetic* is often employed to designate a fourth type of language represented chiefly in aboriginal America, but, as has been shown in another connection, it refers rather to the content of a morphologic system than to its form, and hence is not strictly parallel as a classificatory term to the three we have just examined. As a matter of fact, there are *polysynthetic* languages in America which are at the same time agglutinative, others which are at the same time inflective.

It should be carefully borne in mind that the terms isolating, agglutinative and inflective make no necessary implications as to the logical concepts the language makes use of in its grammatical system, nor is it possible definitely to associate these three types with particular formal processes. It is clear, however, that on the whole languages which make use of word order only for grammatical purposes are isolating in type, further, that languages that make a liberal grammatical use of internal vowel or consonant change may be suspected of being inflective. It was quite customary formerly to look upon the three main types of morphology as steps in a process of historical development, the isolating type representing the most primitive form of speech at which it was possible to arrive, the agglutinative coming next in order as a type evolved from the isolating, and the inflective as the latest and so-called highest type of all. Further study, however, has shown that there is little to support this theory of evolution of types. The Chinese language, for instance, so far from being typical of a primitive stage, as used to be asserted, has been quite conclusively proven by internal and comparative evidence to be the resultant of a long process of simplification from an agglutinative type of language. English itself, in its historical affiliations an inflective language, has ceased to be a clear example of the inflective type and may perhaps be said to be an isolating language in the making. Nor should we be too hasty in attaching values to the various types and, as is too often done even to-day, look with contempt on the isolating, condescendingly tolerate the agglutinative, and vaunt the superiority of the inflective type. A well-developed agglutinative language may display a more logical system than the typically inflective language. And as for myself, I should not find it ridiculous or even paradoxical if one asserted that the most perfect linguistic form, at least from the point of view of logic, had been attained by Chinese, for here we have a language that, with the simplest possible means at its disposal, can express the most technical or philosophical ideas with absolute lack of ambiguity and with admirable conciseness and directness.

UNIVERSITY STANDARDS AND STUDENT ACTIVITIES

By ORRIN LESLIE ELLIOTT

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IN a recent address before the Stanford Forum Professor Barrows made reference to the current criticism and depreciation of the American college. This criticism may be summed up in the statement that the college does not make good. Its output is woefully disappointing. Its business is to prepare young men and women for effective living in their time and place, to equip them for the responsibilities and duties which every generation in turn must meet and discharge if the standards of civilization are to be maintained and pushed forward. The charge is that college graduates do not meet the test; they do not measure up to the requirements; they are deficient in those very qualities which the higher education is supposed especially to nurture.

Professor Barrows would frankly accept the situation: the fact is mainly true; the explanation is that too much has been expected of the college. College students are too immature. As one goes about the campus it is groups of boys and girls that he meets, full of the playtime spirit, not taking learning seriously, their minds filled with games and social functions. Better recognize that it is so, consider the college period as an extension of the playground, and not expect of it equipment for the serious part of life.

Professor Barrows was holding a brief for the graduate school, whose function should be, as he conceived it, to do exactly what it is unreasonable to expect of the undergraduate college. That point I do not wish to follow. But that which Professor Barrows passed off carelessly as an added argument for the graduate school may well be the object of further inquiry. If it is true that the college has failed there is something pathetic in the situation thus presented; because education is the one thing to which democracy has pinned its faith. And the outward progress of education has been all and more than its wildest enthusiasts could have dreamed. From kindergarten to university the wealth of the state has been poured out, and the state's bounty supplemented by unparalleled private munificence, until the highest education is within reach of the humblest youth in the land. Within a single generation, while population has increased but a hundred per cent., the attendance upon institutions of higher education has increased four hundred per cent. The expansion in secondary education has been no less significant. In 1880 there were no four-year high schools in the

United States, and the whole number of secondary schools, public and private, was only 1,400. In 1907 the number had risen to 10,238, an increase of over 700 per cent. And the modern high-school course comprehends a broader training than was given by the college of fifty years ago! Everything would seem to be prepared for college work of the highest efficiency.

By common admission, quite the contrary is the case. Different colleges are differently affected, but the same virus has found its way to all. "The college has lost its definiteness of aim," says ex-President Woodrow Wilson. "There is no question," affirms Mr. Flexner, "that the college is under fire. . . . The college faces the new and unforeseen problems rather helplessly. It is bewildered. . . . Unless I greatly err, the college has already lost a trick or two." "Notwithstanding the enormous improvement and growth in machinery, plant and facilities of our colleges," declares Mr. Birdseye, "their methods and systems are archaic and the average of their product—from the point of good workmanship—has decidedly deteriorated." "The important thing"—I quote from Flexner's "American College"—"is to realize that the American college is deficient, and unnecessarily deficient, alike in earnestness and in pedagogical intelligence; that in consequence our college students are, and for the most part, emerge, flighty, superficial, and immature, lacking, as a class, concentration, seriousness and thoroughness. . . . A youth may win his degree on a showing that would in an office cost him his desk." There is "on the one side a formidable array of scholars and scientists, libraries, laboratories, publications; on the other, a large miscellaneous student body, marked by an immense sociability on a commonplace basis and wide-spread absorption in trivial and boyish interests. How are we to account for the disparity? Clearly the college fails to enlist a respectable portion of the youth's total energy in intellectual effort; either its sincerity or its pedagogical intelligence is discredited by the occupations and diversions which it finds not incompatible with its standards and expectations." "So far as the colleges are concerned," says Professor Münsterberg, "one imperative change stands in the center of every platform: scholarship must receive a more dignified standing in the eyes of the undergraduates. . . . So long as the best human material in our colleges considers it as more or less below its level to exert effort on its studies; so long as it gladly leaves the high marks to the second-rate grinds, and considers it the part of a real gentleman to spend four years with work done well enough not to be dismissed, and poorly enough never to excel, there is something vitally wrong in the academic atmosphere." President Lowell, in a recent address before the University Convocation at Albany, said: "It requires little familiarity with students to recognize that they not only regard the athlete or the man of social prominence as a far more promising personality than the high scholar, but that rank itself is in their minds little or no indication whatever of the qualities that make for success in life. This feeling seems to have been progressive, as is shown by the very words used to indicate the student who works hard. A generation ago he was called a 'grind,' but now he is often referred to as a 'greasy grind,' the adjective, of course, being used to denote contempt. In fact, it may be doubted whether the respect for scholarship has ever been so low in any institution of learning as it is in American colleges at the present day." We may listen also to the breezy catalogue of our neighbor, Professor Gayley. Speaking of the college student, he says: "What with so-called 'college activities,' by which he must prove his allegiance to the university, and social functions by which he must recreate his jaded soul, no margin is left for the one and only college activity—which is study. Class meetings, business meetings, committee meetings, editorial meetings, football rallies, vicarious athletics on the bleachers, garrulous athletics in dining room and parlor and on the porch, rehearsals of the glee club, rehearsals of the mandolin club and of the banjo, rehearsals for dramatics, college dances and class banquets, fraternity dances and suppers, preparations for the dances and banquets, more committees for the preparations; a running up and down the campus for ephemeral items for ephemeral articles in ephemeral papers, a soliciting of advertisements, a running up and down for subscriptions to the dances and the dinners and the papers and the clubs; a running up and down in college politics, making tickets, pulling wires, adjusting combinations, canvassing for votes—canvassing the girls for votes, spending hours at sorority houses for votes—spending hours at sorority houses for sentiment; talking rubbish unceasingly, thinking rubbish, revamping rubbish—rubbish about high junks, rubbish about low, rubbish about rallies, rubbish about pseudo-civic honor, rubbish about girls;—what margin of leisure is left for the one activity of the college, which is study?"

According to the Briggs report of 1904 Harvard students averaged twelve hours of class-room work and thirteen hours of outside work per week, or four hours per day only, devoted to the business of the undergraduate. Four years later the dean could still say: "That the present standard of work 'to pass' is low, the investigations of the Committee on Improving Instruction showed; undergraduates of to-day almost without exception frankly admit it. To obtain the necessary number of 'grades above D' ('the requisite number of C's,' is the common phrase) requires almost no steady, and only briefly concentrated, labor; nowhere except in a college would the work which produces 'the requisite number of C's,' the so-called satisfactory record, be tolerated from youths of equal age and endowment—nowhere else where young men are supposed to be seriously at work is so low a standard in quality endured." In his report of the same year Dean Ferry, of Williams, says: "The spirit of the college is excellent in all respects save that of lack of seriousness toward the work of the class room. Could the undergraduate be made to believe that it is worth while to devote serious and uninterrupted effort to the study of the matter set before him in his college courses, the atmosphere of the college would leave little to be desired."

Mr. Birdseye counted twenty-seven distinct interests and occupations which engage the student in a modern university, outside of the work for which the university exists. "The teachers in our colleges," says Woodrow Wilson, "are men of learning and conceive it their duty to impart learning; but their pupils do not desire it; and the parents of their pupils do not desire it for them. . . . Many of the parents of our modern undergraduates will frankly tell you that what they want for their sons is not so much what they will get in the class room as something else, which they are at a loss to define, which they will get from the associations of college life." Speaking of amusements and athletic activities, he says: "Athletics has no competitor except these amusements and petty engrossments; they have no serious competitor except athletics. The scholar is not in the game. He keeps modestly to his class room and his study and must be looked up and asked questions if you would know what he is thinking about. . . . He deplores athletics and all the other absorbing and non-academic pursuits which he sees drawing the attention of his pupils . . . but he will not enter into competition with them."

In looking about for a scapegoat our critics have found the elective system the most handy. Those who hark back to the old humanistic college, like Princeton's ex-president, and those who recognize that the old has gone forever, like Mr. Flexner, seem to unite on this point. The elective system does well enough for the seriously minded. What does it do for his brother, of opposite inclination? asks Mr. Flexner. "It simply furnishes him an abundant opportunity to exercise a low ingenuity in picking his way to a degree with the least exertion, the least inconvenience in the way of hours, the least shock to the prejudices which function for him in place of ideas, tastes and convictions. He comes out at the spout as he went in at the hopper—except for the additional moral havoc wrought by four years of 'beating the game.'" Woodrow Wilson finds the evil of the elective system, not so much in the easy escape of the loafer as in the heterogeneity introduced, the dilution of the college atmosphere with professional and vocational aims. "It is notorious," he says, "how deep and how narrow the absorptions of the professional school are. . . . The work to be done in them is as exact, as definite, as exclusive as that of the office and the shop. . . . It does not beget generous comradeship or any ardor of altruistic feeling such as the college begets. It does not contain that general air of the world of science and letters in which the mind seeks no special interest, but feels every intimate impulse of the spirit set free to think and observe and listen—listen to all the voices of the mind." Yet Princeton, of all American colleges freest of the taint of the elective system, had become, as described by ex-President Wilson himself, the pleasantest country club in America. Under the preceptorial system ex-President Wilson is now able to report Princeton as a place where undergraduates do a fair amount of good, intelligent work —"but," he adds, "nothing to get excited about"!

President Lowell notes that what has given these twenty-seven occupations—at least the absorbing ones—their fascination is the spirit of emulation which they foster and bring out to its fullest extent. The corrective therefor is to put the spirit of emulation into scholarship, to find the American equivalent to the Oxford and Cambridge dual pass-and-honor system. On this point Professor Münsterberg says: "If we can foster scholarship by an appeal to the spirit of rivalry, by all means let us use it. We may hope that as soon as better traditions have been formed, and higher opinions have been spread, the interest in the serious work will replace the motives of vanity. . . . Of course, no one can overlook some intrinsic difficulties in the way of such plans. No artificial premium can focus on the scholar that same amount of flattering interest and notoriety which the athletic achievement represents, in that little field, a performance which may be compared with the best. The scholarly work of the undergraduate, on the other hand, at its highest point necessarily remains nothing but a praiseworthy exercise, incomparable with the achievements of great scholars. The student football player may win a world's record; the student scholar in the best case may justify noble hopes, but his achievement will be surpassed by professional scholars every day."

In trying to domesticate the Oxford-Cambridge system Columbia has hit upon an interesting principle of segregation, described in the October *Educational Review*. A generation ago few students entered college without the definite desire to obtain a scholarly education. The student body was small and united in aim. To-day conditions are far otherwise. The spread of popular secondary education, the rapid increase and distribution of wealth, have placed a college education within the reach of those lacking both scholarly ambition and the traditions of culture, but to whom have come the opportunity and desire for social betterment. A boy of this sort is sent to college in order that in later life he may mingle freely and equally with college-bred men, that he may learn how to get along with his fellows, and by contact with them have his angularities removed. "It is quite idle," declares

Professor Mitchell, "to object that the college exists primarily for the production of scholarship and the training of scholars. . . . That has happened in collegiate education which is not unknown in commercial industry: the by-products have been discovered to possess unsuspected values, and in the wide-spread popular demand for them a profound change has been wrought in the college clientèle and in the needs which the colleges are called upon to meet. By a very slight and entirely logical extension of the system of free election we could let each take, for an appropriate fee, whatever he might desire of the goods the college had to offer." This deduction Professor Mitchell rejects because "on every side the system of free election has failed and broken into chaos precisely because the college is not a commercial enterprise." "Yet it is equally futile and ridiculous to attempt to make scholars of those who have no scholarly aptitude or ambition." Both kinds, however, may find their satisfaction in the same college, though not, he thinks, in the same classes. For the one class Columbia will provide scholarly training; for the other, something different. In Mr. Dooley's college, when the applicant for admission arrives, "th' prisidint takes him into a Turkish room, gives him a cigareet, an' says: 'Me dear boy, what special branch iv learnin' wud ye like to have studied f'r ye be our compitint professors?'" The Columbia president will not do this; but Columbia's enforced regimen for by-product majors will at least eschew the "futile and ridiculous" attempt to impose scholarship upon them.

I am frank to say that if the analyses represent the case at all fairly, the remedies seem inadequate. The elective system, for example, is a manifestation on the academic side of a transformation which has covered the whole range of college activity. Many causes have contributed to this result. The quickening principle was the German university ideal carried over to the American college by pioneers in that great procession of American youth who have sought the stimulus of German scholarship. Coincident with this has been the development of secondary education and the postponement of the period of college training. When the entering age was pushed up from twelve and thirteen to sixteen, eighteen, and even higher, a change in discipline was necessary. The multiplication of subjects of study made some sort of selection inevitable. If Harvard were to schedule but seventeen courses the elective system could be abandoned—for seventeen courses constitute a four years' program; whereas, if all the courses now offered were prescribed for graduation it would take the student more than seventy years to earn his degree. Of sheer necessity some freedom of choice must be conceded; and the invitation to the student to share in the selective process has been the most clarifying principle in modern higher education. The system has grown because it has worked. The supplanting of the old self-improvement, or culture, theory by the German ideal of scholarship gave a tremendous impulse to serious college work. And with serious college work in hand, both the old paternalism and the childishness of the schoolboy college must necessarily slough off. "I will not ask you to be true to us," President White said at the opening of Cornell University in 1868. "I will ask you to be true to yourselves. In Heaven's name be men! Is it not time that some poor student traditions be supplanted by better? You are not here to be made; you are here to make yourselves. You are not here to hang upon a university; you are here to help build a university. This is no place for children's tricks and toys, for exploits which only excite the wonderment of boarding-school misses. You are here to begin a man's work in the greatest time and land the world has yet known." Cornell students responded to this appeal, and so did students the country over to similar appeals. Throwing dead cats through class room windows, locking professors in their rooms, muffling college bells, levitating domestic animals to third-floor chapels, and like customs, though they died hard, actually died. Definiteness of purpose was given to college study. The new subjects, with their fresh and unexplored fields, absorbed the student and gave him a seriousness his predecessor had lacked. A manlier attitude prevailed. Co-education began to arrive; and in all the state universities particularly, the presence of a body of serious-minded young women did much to elevate the atmosphere of college life. The superfluous energies of youth heretofore wasted in boyish tricks and worse turned to athletic sports, and to developing, one after the other, the twenty-seven activities Mr. Birdseye has noted. The testimony to the improvement in manners and morals within the student body is overwhelming. Petty regulations and rules of conduct atrophied and dropped off. College students began to be regarded and to feel as men and women, with responsibility for their own conduct—to the profit of all and to the immense relief of college authorities.

The flowering period of this cycle may be roughly fixed as the twenty-five years from 1870 to 1895. All went well so long as the impulse set free by the liberalizing of the college curriculum lasted, and while the college constituency was essentially homogeneous. In the later years certain vital changes were taking place, partly as the result of these very movements, partly from influences outside the college. Wealth and luxury became widely diffused. The schools multiplied and were free, and the opportunity of school and college came without effort. Going to college became part of the ordinary routine of a boy's and girl's life. With youths that were earnest there came also to college doors troops of the unearnest. The twenty-seven student activities became more and more engrossing. Within the college boundaries there has grown up a rival institution, with antagonistic aims and ideals, to which the student body gives first allegiance.

If the college faces this new situation rather helplessly, as Mr. Flexner affirms, it is because analogy has here played its old trick. As a matter of fact, absolute election of studies by the student has nowhere existed. But in the wider matters of conduct and in the question whether to study or not to study the college has drifted without any clear principle of action. College students were treated as men and women, with good results. Therefore they are men and women. Therefore whatever the results, they must be treated as men and women with the privileges and responsibilities of men and women. Whatever happens, the college can do nothing except in the sphere of moral influence. As Mr. Birdseye sees it, "substantially all direct control of the personal freedom of the students has been given up except in cases where their action becomes scandalous or they break the public law. . . . The absolute personal freedom, which in many instances is but another name for laxity, undoubtedly tends strongly and constantly to personal shiftlessness and laziness as well as to bad mental and moral habits. . . . With the freedom of their fraternity and club life and the absence of faculty and parental restraint, have come constant distractions from study in connection with a succession throughout the year of class, fraternity, and intercollegiate games of football, baseball, basketball, tennis, golf, chess; of rowing, track and athletic meets; of glee, mandolin and banjo and other musical and dramatic clubs or associations; of receptions and other social functions, of literary dailies, weeklies, monthlies and annuals; and even of intercollegiate debates. . . . In most colleges there has grown up a decidedly false atmosphere, which affects adversely the personal lives of a greater or less proportion of the students." "I know of no place," wrote the dean of a western university to Mr. Birdseye, "where so much fine material coming from the country and small towns has been ruined by a single half-year of idleness and extravagance. The worst elements of city, social and fraternity life seem to be those most eagerly grasped after and most incessantly followed."

Suppose we follow the course of an imaginary freshman at the composite college of our critics; one who is well prepared, with a sense of the importance of his undertaking, and unsophisticated. What he seeks the college has to offer: facilities, scholarly standards, inspiring teachers. It is not at all certain that he will reach his goal. In the first place the scholarly atmosphere is not very evident—to a freshman. For days, weeks even, before the opening old students have drifted in. They have not done this in order to consult the authorities the better to plan and prepare for the studies of the year. They have plans of their own. They are at starting the wheel within the wheel.

They are about the planning of courses in athletics, in dramatics, in rushing, in tubbing, in college traditions generally. They have their own uses for the incoming freshman class, and their own elaborate and trying admission requirements. They condescend to notice the faculty's college when it becomes necessary to take their protégés in tow and make a dead set against some assumed weak spot in the college's entrance defenses. Mostly, to the freshman's eye, there is a whir of automobiles, a rushing to and fro with excited conferences over innumerable projects which bear little relation to the ideals with which he set out from home. The conversation he hears is not of studies or ideals of study. The standards of conduct, of appreciation of priceless opportunity, are what might be expected of a generation brought up on the modern daily newspaper, with town and city environment, whose fathers will set them up in business when college days are over, and who will take with ill-grace and much contempt of regulations the little learning they can not avoid without risking the pleasures and excitements which chiefly mark their progress toward a learned degree. If the freshman is put wise early he learns to submit with as much composure as possible to whatever rough treatment of his own person the college world decrees as appropriate to his crude state of development: the college authorities not being in this game, either. If above the hubbub his ear catches the announcement of an address to the entering class by the president of the college on Thursday evening, he knows that is a signal for special activity on the part of his sophomore friends. Consequently he stays in his room—unless, perchance, constrained to come flying forth in unceremonious fashion. But if the meeting be advertised for midday he may hear, for a moment, an echo of those ideals and principles which had beckoned and fortified him as he made his decision for a college course. This impression, however, is quickly swallowed up in the whoop-er-up speeches and cheers in behalf of college activities, in which the faculty seemingly participates with equal abandon. On registration day, for a brief space the college once more seems to hold sway; then it and its ideals fade into dim distance, while the real, absorbing college of student life resumes the scepter. When classes begin he follows instinctively a habit not yet outgrown, and essays to enroll with his instructors. But the freshman who had been something of a leader in his home school, who was thought to have learned a measure of self-reliance, who had even filled a position of responsibility in a very real experiment in self-government, now finds that he has by no means learned his place. While the academic sideshow of lectures and recitations is getting itself started in halting fashion, the freshman is in the fierce struggle and joy of real college life. As free of conventional wrappings as nature made him, he is paraded and tubbed in open daylight around faculty lawns and by campus houses, and whiles away the forenoon in stunts which teach him his place some more and further his initiation into that innermost, sacredest circle, the knights of the college tradition. Since nothing can be done unless you get student sentiment behind it, the faculty sits in helpless inactivity; or, if the emotions are much stirred, rushes to its laboratories and attempts to think out some serum which will work upon the student mind and permit it to look with favor upon the studies of the college curriculum!

At last, it may be, the freshman is started in his studies. But attending classes and studying lessons is not as he had pictured it. The men whose names and imposing academic biographies had awed him from the pages of the college catalogue he must now learn to look at from the angle of his sophisticated companions. This one, frankly, is a chump; this other can be counted on to do the fair thing and not flunk a fellow; that one will be down on you anyhow. One is to be worked in one way; another, in another way. In this class you can safely cut as much as you like; in this other it is necessary to look after answering roll call. The main object is to keep from flunking out; for as yet absolute immunity has not been achieved, and real college life is too pleasurable to be hazarded too far. Getting something from the course is at least secondary. Getting the credit at present seems necessary, and, when hard pressed, one's wits need to be well sharpened. Why should one be too scrupulous, since it is only the book account that matters? Bluffing runs naturally into something more effective, and the freshman sees the game of cheating going on almost as a matter of course. Sometimes the instructor seems to him to be aware of the game, but too embarrassed to call for the cards; can not afford, in fact, to become unpopular, for may not the instructor's comfort, not to say his standing in the college, depend on the good will of the student? Once in a while the committee—blankety symbol of all that is hateful in an otherwise lovely environment—the committee connects with some luckless offender, who, bruised and bewildered, presently finds himself at the edge of the campus. All of which would be tragic, were it not so grotesque, for but a single head has been hit out of a multitude just below the line of breastworks. More and more absorbing are the activities of the college of student life; more and more the faculty's college and its obtrusive exercises become an incubus, more and more its occasional interferences become irritating and objects of student wrath. Dissipation masks as good fellowship. The grosser temptations lose horns and hoof. The freshman himself may be nor athlete, nor actor, nor editor, nor society devotee. But he learns to be vicariously active in all these pursuits; in an atmosphere of hazing, shamming, bleachering, beating the game, his whole moral and intellectual structure suffers irreparable shock.

Let us hasten away from this impossible college and come back for a brief space to the real institution, in which nevertheless some portion of this virus is at work. And first, it is safe to say that the day is not to be saved by a return to fixed programs of study made out of faculty piecings. Nor can Woodrow Wilson, or his successors, succeed in drawing off from the great mass of undergraduates the saving remnant foreordained to be separated for four years from all training that bears upon a special task—attractive as that ideal may be. Nor will President Hadley's ideal—"where a student learns things that he is *not* going to use in after life by methods that he *is* going to use"—ever again dominate the college. President Wilson found the work of the professional school "as exact, as definite, as exclusive as that of the office and the shop." The college can stand a large infusion of this ideal. Columbia's plan of providing an academic annex for majors in dullness, athletics and social functions seems none too promising. The junior college, and other compartment arrangements, useful perhaps as administrative makeshifts, are futile as attempts to segregate differing ideals of education.

In turning to greater administrative efficiency as a remedy, one can not but sympathize with the gentle plaint of Professor Showerman: "The professor thought of the administration of his college—of all the regents, registrars, clerks, secretaries, committees, and advisers, of all the printing and writing and classifying and pigeonholing, of all the roll-calling and quizzing and examination. What was all this marvellous system for? Why, simply this: in order that young men and women who came to college to get an education might be prevented from avoiding the very thing they came for!" Humiliating as the admission may be, that is about what it has come to. Of regents and registrars and pigeonholing and classifying we have perhaps a sufficiency. But of that concern for what Mr. Birdseye calls the student life department—ninety per cent. of the student's actual time—there is, alas, not a sufficiency.

Professor Barrows, who frankly abandons the undergraduate college as a period of serious intellectual effort, would still think of it as a moral opportunity—not for courses in ethics and formal moral teaching, I take it, but that by some process or other these bright, alert girls and boys might be enough arrested in their absorbing play to see, in the scholarly atmosphere shed from above, in the quiet ideals of the cloister, in generous comradeship with generous comrades, a moral quality and beauty that should win their allegiance and emulation. As a matter of fact, there has been too much reliance on the theory that somehow, through the mysterious processes of providence, just spending four years in college is in itself a saving and redeeming grace; that somehow shamming, and dissipation, and moral lapse in college do not count in later life—since these also are exercise and training in the rights and responsibilities of manhood and womanhood. "One way to deal with these strange, excited, inexperienced and intensely human things called freshmen," says Dean Briggs, of Harvard, "is to let them flounder till they drown or swim; and this way has been advocated by men who have no sons of their own. It is delightfully simple, if we can only shut eye and ear and heart and conscience; and it has a kind of plausibility in the examples of men who through rough usage have achieved strong character. 'The objection,' as the master of a great school said the other day, 'is the waste; and,' he added, 'it is such an awful thing to waste human life!'"

A great mob of boys and girls are thronging the entrances of our colleges and universities. All need, most are entitled to, training; but not all are fitted and adapted to the college. Some ought to be in the shops and marts and homes acquiring discipline by contact with hard realities. Some are morally tainted and impervious to intellectual appeal. The mass is plastic and possible of development into capable, self-reliant citizenship. If the college can not find out these facts, who can? If the college can not rid itself of the unworthy, who is to do it? If the college can not make its standards dominate the college world, how can its work become effective? Up against these problems, the college must plead guilty to the charge of carelessness and ineffectiveness. In a situation where youths are on the way to manhood and womanhood, but not yet arrived, where standards are necessarily blurred and confused, the college has been more or less helpless, because it has not squarely faced the problems involved. It must be said again, the college can not go back into the old boarding-school chrysalis. Athletics, amusements, student activities, exercise of responsibility, were all welcomed into the college as aids to normal living, as making student life more wholesome. And so they were, and did. Paradoxical as it may seem, these are not yet widely enough diffused. We have come to our present plight because the college has had no consistent conception of its function in these matters. Harvard has retained the genial loafer for the possible good that might come "from contact between his back and the bricks of the college." But what about the contagion of his presence in a place where sound standards have to struggle to keep even a foothold? Other institutions have sought to rigidly exclude those who did not measure up to a fixed standard, though by a rough surgery that has sometimes seemed to treat measles and appendicitis pretty much alike. "It is comparatively simple," says Mr. Flexner, "to extirpate those who appear to be the weaker brethren; but it is not a whit more intelligent than to pull every aching tooth." Yet the aching tooth needs attention, and it must come to pulling at last, if nothing else is done.

Again, faculties are adjured to become acquainted with their students and to pay them social attentions. Excellent advice—usually where it is not needed! Occasions may not be forced. Social relations spring normally out of other relations. Instructors may rightly be reminded of responsibility and duty, but the up-to-date college, as Mr. Birdseye would phrase it, can not rely on untrained, voluntary service where training and unremitting attention are needed. Nor can the college turn to its dean or adviser and demand of him the physical impossibility of knowing every student and his particular problems and needs.

We may look hopefully to the preceptorial experiment of Princeton; as also upon the system of advisers which California and other institutions are developing with a view to giving the stumbling freshman the guidance he needs, and to saving as much material as possible from the college scrap-heap. There is promise also in the serum treatment of President Lowell, and one may reasonably expect the academic doctors, in the end, to produce a really valuable compound.

Yet these are only palliatives. The effective solution of the problem—the relation of student activities to university standards—is so simple that I hesitate to mention it. *It is that the college take charge of its own affairs.* Through these later years alma mater has been piling up her equipment, employing more and more professors, proclaiming her wares, absorbed in the task of growing. With some uneasiness, but with affected unconcern, she has seen growing up over against her own growth this monstrous structure of student activities, this artificial world of student life encased in traditions too sacred to be scrutinized and presided over by that stuffed goddess of liberty known as college spirit. Remembering that she once relieved herself of all *in loco parentis* functions and that all her students are men and women, alma mater has walked gingerly around this mountain and tried her level best to fit into the place assigned her. It is alma mater who has failed to notice the aching tooth or connived to conceal its existence from the doctors of the scholarship committee. It is alma mater who has permitted athletics and dramatics and the social whirls and editorialing and the rest of the twenty-seven activities to go beyond the limits of safety and sanity. It is alma mater who can not bear the responsibility of dropping men from college, who, obsessed with the idea that goodness is not created by legislation, thinks only of serums that may influence student sentiment or grasps at Columbia's peptonized diet as a means of providing degrees for those quite divorced from college study.

Alma mater's helpless concern recalls Mrs. Stetson-Gilman's encounter with the obstacle. Climbing up the mountain one day, she finds a prejudice blocking the path, cutting off the view, and absolutely refusing to move. She makes polite request, she argues, she scolds, she implores—all of no avail.

So I sat before him helpless,
  In an ecstacy of woe;
The mountain mists were rising fast,
  The sun was sinking slow—
When a sudden inspiration came,
  As sudden winds do blow.

I took my hat, I took my stick,
  My load I settled fair,
I approached that awful incubus
  With an absent-minded air—
And I walked directly through him,
  As if he wasn't there.

Actually the only reason why these twenty-seven activities do not stand in their proper, subordinate place—are not at once put where they belong—is the inconstant will of alma mater.

When, however, I said that the remedy was simple, I did not mean that it could be applied any how, any way. The means deserve careful thought and the exercise of such good sense as colleges may reasonably be supposed to command. But the main point is the will and determination of alma mater to have, and to have respected, standards of undergraduate conduct and achievement. In the face of such determination the loftiest structure buttressed by college tradition is a mere house of cards. Happily the mind of youth is plastic, and the hoariest college custom may on occasion be treated exactly as if it wasn't there. Certain qualities of heart and mind, with generous effort to improve opportunity, are minimum qualifications for membership in a college. The college has the duty and the authority—may it also have the courage—to set up and maintain standards which will justify indeed, and increasingly, democracy's faith in education.

THE PSYCHOLOGY OF MENTAL DEFICIENCY

By BIRD T. BALDWIN, Ph.D.

UNIVERSITY OF TEXAS

Come wander with me . . .
Into regions yet untrod,
And read what is still unread
In the manuscript of God.

THIS thought, which a few generations ago was uppermost in the mind of the great Agassiz when making his geological explorations, is to-day finding one form of expression in the scientific laboratory for psychological research at Vineland, N. J., where investigations are being made on the causes and conditions of human degeneration and mental deficiency. More vigorously to-day than ever before in the history of civilization, social, educational and psychological investigations are being carried into all phases of life with its misery, happiness and usefulness. Associations for charities, children's aid societies, guilds, juvenile courts and public school authorities, are asking the psychologists and physicians what can be done with these unfortunate people, the mental defectives, who are contaminating society by their presence, absorbing the time and thought that should be devoted to normal children, and later filling the almshouses, charitable institutions and prisons with illegitimate and irresponsible offspring.

The psychologist who analyzes, classifies, describes and explains mental phenomena is beginning to work effectively on the insane, the criminal and the defective. From a psychological standpoint, the border line between dull, backward and retarded children and those mentally defective, lies in a difficult and unexplained region. The inadequate knowledge of mental capacities and the desirability of accurately expressing the relative educational values of such capacities makes the field a most fertile one for research. With others, Ayres and Gulick have been studying the "laggards of our schools" for the Russell Sage Foundation, and Witmer, a pioneer in the field, has established the *Psychological Clinic* for the study of the normal development of every child. What of truly subnormal and mentally deficient children?

The study of mentally defective children began in 1797 when some French soldiers found "the wild boy of Aveyron" in a forest and had him taken to Dr. Pinel, of Paris, for examination. Pinel pronounced him incurable, which caused the publication of a pamphlet three years later by Itard, "De L'education d'un Homme Sauvage." This was the first important contribution to the literature of the subject; the second

FIG. 1. A CORNER OF THE PSYCHOLOGICAL LABORATORY WHERE DR. GODDARD CONDUCTS HIS EXPERIMENTS. There are shown an ergograph, a chronoscope, which measures intervals of time to one thousandth of a second, a dark room for photographic work, an automotograph for recording involuntary movements of hand and arm, a target for testing precision in motor control, etc.

was from one of Itard's pupils, Seguin, who, in 1846, published his valuable work on the physiological treatment of mental defectives. About the middle of the last century, institutions for the care of defectives began to be organized throughout the world, and in 1904 Germany had 24, Sweden 33, England 12 and the United States 30 such homes. At the present time twenty-six of our states have a sum total of 25,000 children in institutions for feeble minded. The Vineland institution, in New Jersey, is one of the most progressive, and the psychological movement for which it stands is rapidly growing in importance and has many followers throughout this country and in some sections of Europe and Canada.

The best studies of the mentally feeble and defective have been made by Itard, Seguin, Howe, Powell, Ireland, Shuttleworth, Tredgold and Barr; among the psychologists who are formulating and trying out individual tests and finding methods of making mental diagnoses are Binet, Simon, De Sanctis, Meumann, Stern, Norsworthy, Thorndike, Goddard, Witmer, Huey, Whipple, MacMillan, Wallin and others; among physicians working in this field are Krenberger, Fernald, Wylie and Healy. One of the places where this study is being most successfully carried out is at Vineland, which has exceptional opportunities for research work because the institution is under private management as well as under state patronage, and it was here a psychological laboratory was founded in 1906, which was the first to be permanently established in an institution for the care of mental defectives. The field is new and full of promise and the movement is rapidly growing in value and influences. This institution has comparatively few children (390 in all) and many of these come from wealthy families whose ancestry is known or from families who have lived in New Jersey for several generations. There are few communities of such stable population and so much inter-family marriage.

Institutional life and training is inferior, most of us will agree, to that of even a mediocre or low-grade home, but there are at least two groups of individuals who are exceptions to this general rule, the feeble minded and the insane. Both are *par excellence* individuals of state concern and state protection because they are incapable of self-direction, self-control or self-support. The defectives, who are by-products of unfinished humanity, belong in institutions where they may be cared for, made happy and to some extent useful, and where they may be studied for the betterment of civilization.

Lines of Investigation at Vineland

Dr. H. H. Goddard, Superintendent Johnstone and their field workers, are spending much time at present on the problem of *eugenics*—study of heredity. The home of each inmate has been carefully canvassed in order to get data which may throw light on the problem of heredity. What has been the result? Three concrete cases will suffice to indicate general tendencies.

1. An alcoholic insane paternal grandfather, a tuberculous cancerous maternal grandmother, imbecile mother with feeble-minded sister married to imbecile father. Result: Five feeble-minded children, one dead, one in custody, all the rest at large.

2. An insane father, a feeble-minded mother, seven children all mentally deficient; one in proper custody, one married, three in almshouse with mother.

3. A feeble-minded paternal grandmother, a neurotic maternal grandfather, an alcoholic father, a neurotic mother with a "queer" sister; ten children, eight feeble-minded children, two uncertain; one of this family in proper custody.

All of the children indicated "in custody" are at Vineland.

Proper care of the feeble-minded and epileptics would prevent this dangerous class from running at large and would help to solve the fundamental problem of the causes of mental deficiency (Figs. 2 and 3).

What are the controlling conditions of heredity? What are the results? The accompanying heredity charts which have been marked out with great care indicate controlling tendencies and suggest the question, Is Mendel's Law of Heredity, which has been proved for plants and animals, applicable to human beings? This is another important

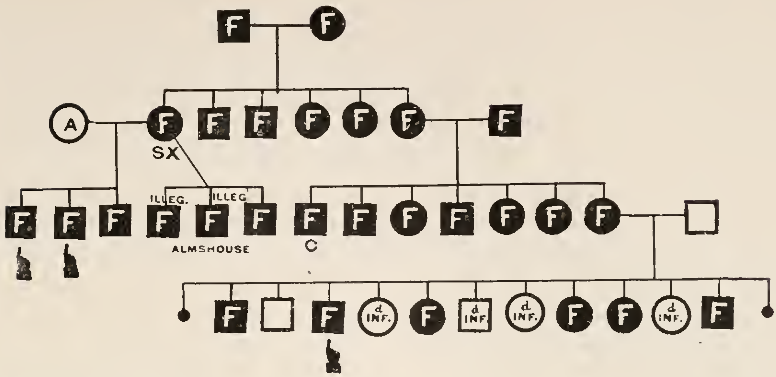


FIG. 2. HEREDITY CHART. Devised by Dr. Goddard, of Vineland, recently adopted by the American Association for Study of Feeble-minded and the American Institute of Criminal Law and Criminology and also used by Dr. Wm. Healy in his work in the Juvenile Psychopathic Institute of Chicago. This chart gives in graphic form the hereditary status of some cases at Vineland, N. J. Square = males; circle = females; clear square or circle means no data; *F*, feeble-minded; *A*, alcoholic; *T*, tuberculosis; *N*, normal; *C*, criminal; *Sx*, grave sexual offender; *d.inf.* means died in infancy; small black dot means miscarriage. Hand points to the child that is in the Vineland institution.

At the present writing three hundred and nineteen members of this family have been traced, one hundred and nineteen are feeble-minded and only forty-two are known to be normal.

problem being pursued. Dr. C. B. Davenport, who is the best authority in this country on eugenics, writes in a paper, soon to go to press, as follows:

Application of Mendel's Law to Human Heredity

For our purpose Mendel's law may be regarded as consisting of three principles. First, the principle of the unit characters of inheritable unit, each of which is, in accordance with the second principle, transmitted through the germ by a representative called a determiner. The third principle is that when the germ cells of both parents carry a determiner of a character the fertilized egg and the embryo derived from it have the determiner of the character double or

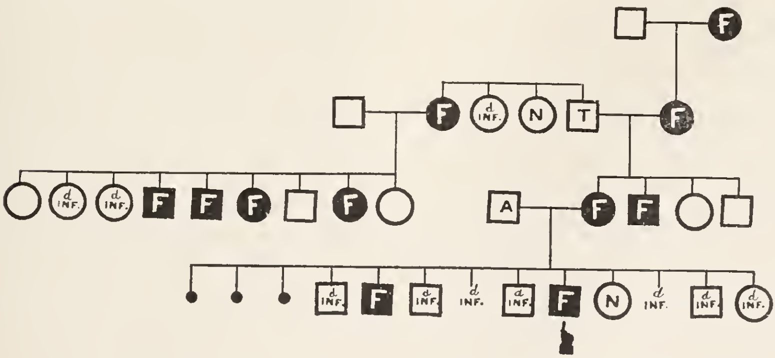


FIG. 3. THESE CHARTS ILLUSTRATE ONE TENDENCY IN THE THREE CASES JUST CITED, *i. e.*, mentally defective parents are very prolific. A very careful study made by Dr. Tredgold in England revealed the fact that sixteen mentally defective women working as mill hands had given birth among them to one hundred and sixteen children.

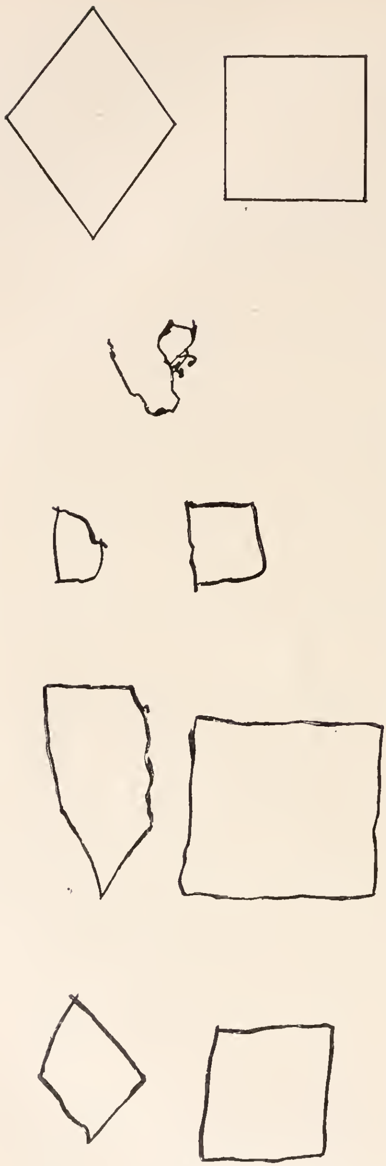


FIG. 4. DRAWING TEST. The upper drawing when reproduced by children of different ages indicates their mental development. The first copy shown, drawn by a white female aged eleven years, indicates a mental development of four years; the second, by a white female aged sixteen years, a development of five years; the third, by a white male aged eighteen years, a development of six years, and the fourth, by a white male aged nineteen years, a mental development of seven years. Reduced to one half.

duplex. When the germ cell of one parent only carries the determiner, this is simplex in the embryo. When neither parent carries the determiner the embryo is devoid of it. It follows that, if neither parent has a character none of their children can have it. If both parents have the character in question simplex, one fourth of their children will be without it; one fourth will have the character duplex and half will have it simplex again.

During the past ten years the study of the characters of plants and animals has revealed the nearly universal validity of this law—and during the past two or three years it has been shown to apply to many human qualities.

The law appears clearest in this form—when both parents lack a unit character all of their offspring lack it. Illustrations of this law are seen in the case of brown iris pigment. In case both parents lack it (and have blue eyes), all of their children have blue eyes. In case both parents lack curved hair all of the children have straight hair; if both parents have flaxen hair, the children are all like them; if the parents are blonds, lacking abundant skin pigment, so are their children. If both parents are defective in mental development, being imbecile, their children are all defectives.

When one parent is defective and the other has the additional character the children will have the character; but, since they get it from one side of the house only, the character is apt to appear in a diluted condition. Thus it may be confidently expected that the children of an imbecile and a normal parent will not all be as mentally strong as the stronger parent because their mental development depends on a simplex determiner.

The committee of eugenics of the American Breeders' Association has established headquarters at Cold Spring Harbor in the vicinity of New York City. It desires first to assist in a propaganda for the study of pedigrees of the feeble-minded. It wishes to urge upon every training school the desirability of supporting at least one field worker who shall visit the homes whence come defective pupils and determine the mental condition of other individuals of the same germ plasms as are united in the pupil question. The Vineland School has set a shining example of this work and has achieved striking results. These studies really ought to be carried on in every state, not merely to confirm the laws of heredity of imbecility but to determine the main blood lines of imbecility coursing through this country.

So far we have considered the causes of mental deficiency of hereditary origin. The causes in general may be grouped roughly under direct, which are due to heredity or disease, and indirect, due to sense defects and accidents. About 85 per cent. of the cases may be traced to conditions prior to birth, such as bad heredity, neurotic conditions, alcoholism and tuberculosis. Injuries at birth are at the present time rare and are responsible for not over 1 per cent., according to the best authorities. The remainder may probably be counted for by accidents, infectious diseases, epilepsy, malnutrition, etc., after birth.

FIG. 5. PLACING BLOCKS IN THE FORM BOARD. With this form board, another type of test used in America, the child is required to place the ten blocks as rapidly as possible in their respective places. The experimenter observes and notes superfluous and jerky movements, the adoption of a method or system, *i. e.*, hunting the block to fit the space and *vice versa*, the ability to profit by experience when the test is repeated, the ability to increase a set pace of procedure, the degree of sustained attention, the span of motor control, and many other phases of mental expression. One bright boy of ten recently placed the blocks in their respective places in twelve seconds and a defective of nineteen required, after much urging and many vacillating and uncoordinated movements, seven minutes and eighteen seconds. Dr. Healy, psychopathologist for the Chicago Juvenile Court, has modified this type of form board by having the geometric forms a part of a puzzle picture which covers the face of the board.

This test alone throws much light on the mind of a child and may be used as a diagnostic test for children of varying grades of arrested mental ability.

FIG. 6. A TEST FOR REFLEX ACTION AND MOTOR CONTROL. The apparatus as shown consists of a piece of glass in a frame which is struck by a rubber hammer. Low-grade defectives seldom wink.

Another line of activity in the Vineland research department has been the gathering of statistics on physical growth of defectives. A report of this work may be summed up as follows:

The lowest grades (idiots) are from two to four inches shorter and from five to fifteen pounds lighter than normal children of corresponding age.

The middle grades (imbeciles) are less than half this amount below normal, while the highest grades (morons) do not differ appreciably from normal children except that there is a tendency to become heavy.

Commenting on these results Dr. Goddard writes, "Normal children begin to grow fast at about eleven years. Among defectives this acceleration does not come until two years later, but when it does come it is a greater acceleration than in normals. This is not yet accounted for but it suggests that it may have an important bearing upon our treatment of school children at that critical age of eleven to fifteen."

The difficulty with these measurements, like all others on normal children, is the fact that they are based on one measurement of a large number of individuals and not on repeated measurements of the same individuals. An investigation soon to be published by the writer shows that two characteristics of growth of which Dr. Goddard has found true of deficient children, are characteristic of normal children as well. That is they naturally form two groups at adolescence, the short boys and girls beginning their rapid growth from one to two years later than the tall boys and girls, and there seems to be a direct correlation between rapid growth at adolescence and the advent of puberty for both boys and girls, the shorter ones maturing later than the tall ones.

Classification of Mentally Deficient Children

Dr. Howe, who is best known from his work with the blind, attempted to group all mentally deficient children under the headings "simpletons," "fools" and "idiots," but the most widely accepted classification to-day is that of Dr. Barr, of the Elwyn Training School, Pennsylvania, who classifies them as "feeble-minded," "imbeciles" and "idiots."

A new classification has recently been adopted by the American Association for the Study of the Feeble-minded. It is functional rather than physiological and is as follows:

Mental Age	Capabilities	Class	
Under one year,	Helpless.	Low	Idiot.
1 year,	Feeds self. Eats everything.	Middle	
2 years,	Eats discriminatingly.	High	
3 years,	No work. Plays little.	Low	Imbecile.
4 years,	Tries to help.		
5 years,	Only the simplest tasks.	Middle	
6 years,	Tasks of short duration. Washes dishes.		
7 years,	Little errands in house. Dusts.	High	

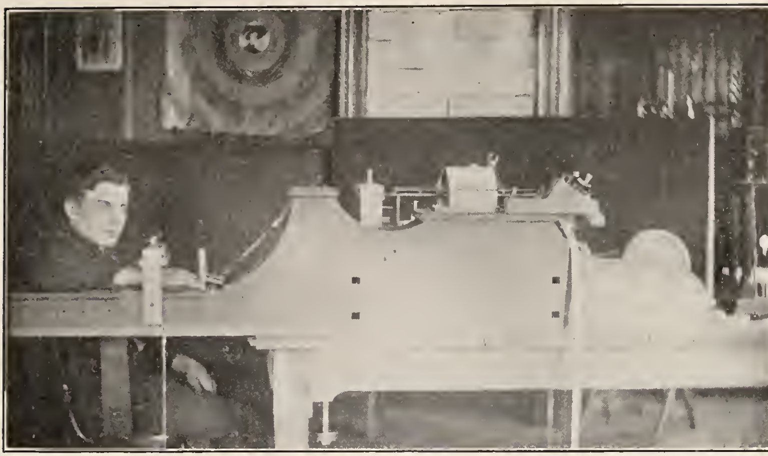
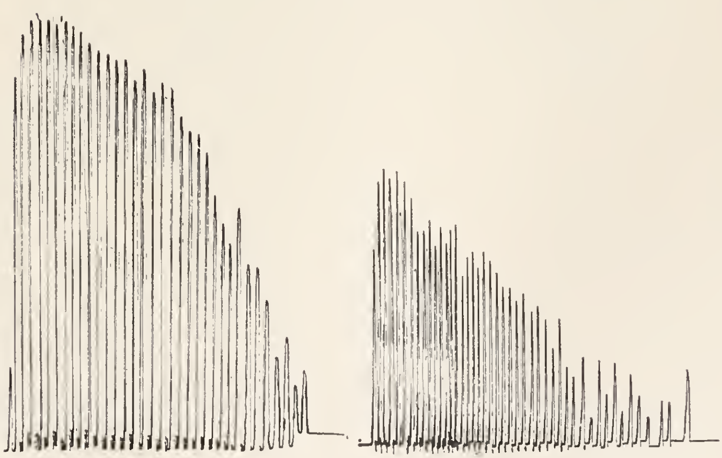


FIG. 7. AN EXPERIMENT IN ACTION WITH THE ERGOGRAPH.

Mental Age	Capabilities	Class	
8 years,	Errands. Light work. Makes beds.	Low	Moron.
9 years,	Heavier work. Scrubs, mends, lays bricks, cares for room with simple furniture.		
10 years,	Good institution helpers. Routine work.	Middle	
11 years,	Fairly complicated work with only occasional oversight.		
12 years,	Uses machinery. Cares for animals. No supervision. Can not plan.	High	



FIGS. 8 and 9. ERGOGRAMS. Records of a normal man and of a defective boy, the latter showing characteristic irregularities.

The ergograph was devised by Mosso, an Italian psychologist, and is used to measure muscular fatigue. A weight is lifted with one finger every alternate second until the muscle is tired out. Each lift is recorded on a vertical line and the sum total of lifts and lengths of lines are indicative of muscular action and voluntary control.

An idiot, according to this classification, can not reach a degree of mentality beyond that of a normal child of three years, an imbecile beyond seven and a moron beyond twelve. This has been determined by means of a series of tests.

Mental and Physical Tests

There have been several attempts during the past fifteen years to formulate a series of graded tests which will evaluate children's span of intelligence and measure mental defects by means of comparison with posited norms. Binet has been at work longest trying to formulate such tests and with some success and while the Vineland and Lincoln institutions are adopting the Binet and Simon tests for work with feeble-minded children, the University Elementary School, of the University of Chicago, and the Psychopathic Institute, of the Chicago Juvenile Court, are establishing norms for normal American children.

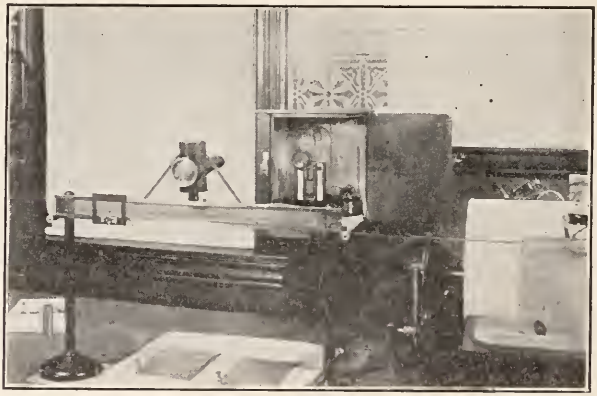


Fig. 10. Psychometer. The psychic galvanometer or psychometer, which is used to detect delicate physiological changes which accompany the emotional experiences of children. This apparatus is also used in psychological methods for detecting crime, although the nature of the phenomena giving rise to the galvanometric deflections is still an open question.

The Binet and Simon tests throw little light on the moral or physical nature of the child, and they do not allow for sense defects, which would naturally affect a child's standing, even though normal in other respects. The latest edition of these tests takes into account the age of the child, and eliminates almost entirely the factor of training by measuring what the child learns fortuitously. They thus form a "measuring scale for intelligence" and are of direct value and interest to all parents and teachers of normal as well as backward or defective children. The fifty-seven tests cover the period from three to twelve years, and if a child succeeds in the tests derived for his age, he is normal; if he can succeed only in the test devised for a child one year younger, his development is arrested to the extent of one year, and similarly for two or three years. If he is unable to do the tests for more than three previous years, he is mentally defective and his mental age is determined by the tests which he can accomplish.

The test for a child of six years of age mentally is as follows: Shows right hand, left ear. Repeats sentences of 16 syllables. Distinguishes pretty from ugly or deformed faces, in pictures. Defines, in terms of use, the words table, chair, horse, mama. Performs three commissions given simultaneously. Knows age. Knows whether it is forenoon or afternoon.

Fig. 11. An apparatus devised by Dr. Goddard for testing the ability to recognize objects by the sense of touch (stereagnostic sense).

The tests for seven are: Notes omission of eyes, nose, mouth or arms, from portraits. States number of fingers on right hand, left hand, both hands. Copies written sentences, with pen, so they can be read. Draws diamond-shaped figures from copy (child of mentality of six years can not do it. See illustrations, Fig. 4.) Repeat five numbers in order, when heard once. Describe a picture shown. Counts 13 pennies, one by one.

Fig. 12. The Maze Test for Motor Control. Reduced to one half. A device first used at Columbia University for testing the ability to trace the white line in a given interval of time. Frequent contact with the sides indicates poor motor control. High-grade feeble-minded children usually make from 60 to 100 contacts. The tracing reproduced was made by an epileptic and contains 84 contacts.

Mentally defective children seldom reach the mentality of a normal child of twelve years, who can meet the following requirements. Rearranges shuffled words of eight-word sentences. Repeats seven numerals in order, when heard once. Names three words that rhyme with obey, in one minute. Repeats, with no errors, sentences of 26 syllables. Infers a fact from given circumstances which indicate the fact.

Three hundred and seventy-eight defectives at Vineland have been tested with the complete Binet tests with the following results:

Mental Age	Boys	Girls	Total
1	25	11	36
2	25	12	37
3	21	19	40
4	30	7	37
5	29	13	42
6	30	9	39
7	30	17	47
8	33	11	44
9	23	7	30
10	7	7	14
11	5		5
12	5	2	7
	263	115	378

The following photographs show types of tests, used for making mental diagnoses of children at Vineland, the Lincoln Institution in Illinois, the University of Chicago, the Chicago Juvenile Court, Columbia University, University of Pennsylvania, University of Washington, University of Texas, and similar institutions (Figs. 4 to 14).

The foregoing tests and experiments show that mentally defective children offer excellent material for psychological investigation, since they are a more or less isolated group with quite definite boundaries and are dependent on others. They may be observed continuously during their lifetime, they are incapable of being stimulated or enthused by artificial reactions, they are not easily embarrassed or self-conscious; some of their mental processes are slowed down, others almost eliminated and some grossly exaggerated; their motor reactions are usually the direct result of their ideas with little inhibition, decision, choice or judgment, and may therefore be considered fairly safe criteria of the concomitant mental activities. The various stages of mental deficiency frequently parallel the stages of development of the normal mind and since the defective mind may remain for a lifetime at a given level, it may be studied in such a manner as to shed much light on the corresponding stages of the developing mind of the normal child, which is so fleeting in its passage to higher levels.

Finally: 1. Defectives are worthy of careful study for their own sake, for the welfare of society, and for the scientific insight they offer into the mental processes of normal children and the problem of education.

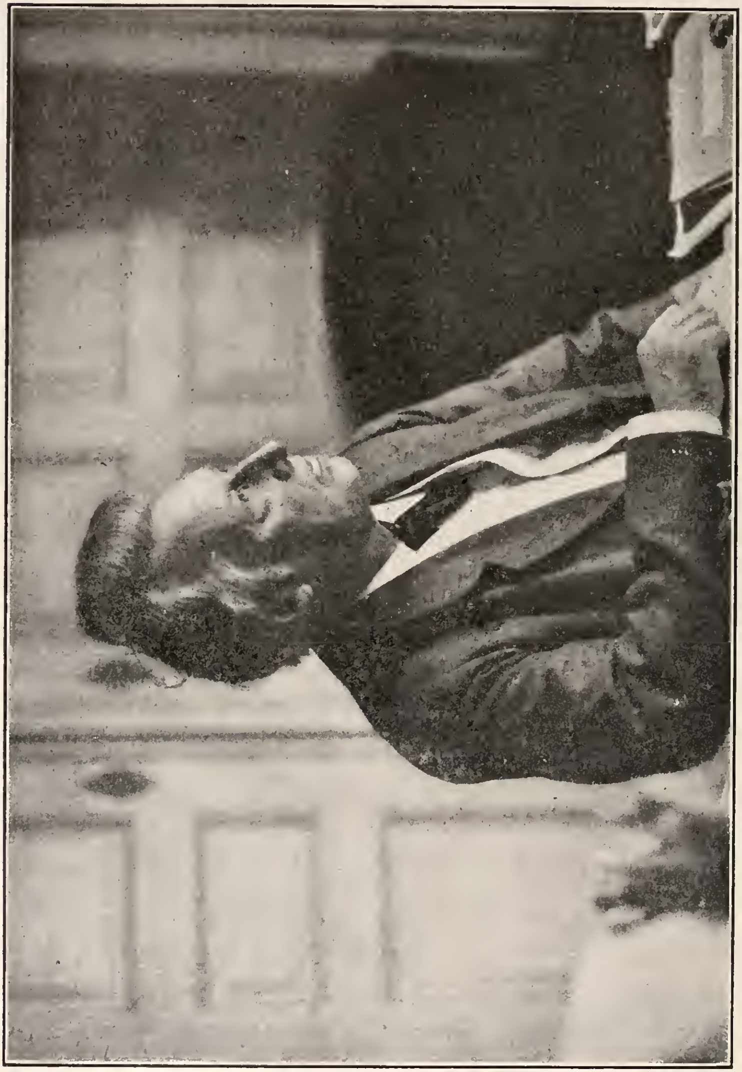
2. They offer, where their ancestry may be traced, the best material at present available for the study of human heredity on account of the pronounced deviations which may be traced.

3. They have so far contributed most to the scientific application of "mental and physical tests" which dominates contemporary tendencies in child psychology and its application to education.

4. Mental defectives present tremendous sociological difficulties in

FIGS. 13 and 14. PRECISION TESTS IN MOTOR CONTROL. The girl in the picture is a high-grade imbecile and is able to thread this large needle and touch the copper points with the stylus. A child of slightly lower grade could do neither.

the advancement of our present-day civilization and educational progress. As cure is impossible, the two chief sources of prevention suggested are to keep such people segregated in institutions and to prevent marriage. Other means may in extreme cases be justifiable; sometimes sterilization is found advisable, but popular opinion usually rebels against such measures.



JACOBUS HENRICUS VAN'T HOFF

BY PROFESSOR HARRY C. JONES

JOHNS HOPKINS UNIVERSITY

THE death of Van't Hoff removes one of the leading men of science not only of this age, but of all time.

Born in Rotterdam in 1852, the son of a physician, he received his early training in the Realschule in Rotterdam and in the Polytechnikum in Delft. At twenty he had completed his work in the University of Leiden. He then studied under Kekulé in Bonn and Würtz in Paris, and obtained the Doctor's degree at Utrecht, at the age of twenty-two.

Van't Hoff, in 1876, was appointed privatdozent in physics in the veterinary college in Utrecht. In 1877 he was called to Amsterdam as lecturer in chemistry, and was appointed professor of chemistry in 1878, a position which he held until 1896, when he accepted a call to a chair created for him at Berlin. He held this chair and was also a member of the Berlin Academy of Sciences until his death on March 1, 1911.

Van't Hoff did three great things. His early work was with Mulder in Utrecht, Kekulé in Bonn and Würtz in Paris, and therefore, in organic chemistry. He raised and answered the question, what is the arrangement in three dimensions in space of the atoms in the simpler compounds of carbon? Henri had shown that the four hydrogen atoms in marsh gas (CH_4) all bear the same relation to the molecule. The geometrical configuration of this molecule follows of necessity from this fact. The only geometrical form in three dimensions in space fulfilling the condition of a central object surrounded symmetrically by four things of the same kind, is the regular tetrahedron. Thus arose the theory of the "tetrahedral carbon atom."

Some compounds of carbon rotate the beam of polarized light to the right, others to the left—are "optically active," as they are termed. Pasteur had pointed out that this is possible only in compounds in which there is some kind of asymmetry. Van't Hoff showed in what the asymmetry consisted. He showed that all optically active compounds of carbon then known contain a carbon atom in combination with four different atoms or groups, and the same holds true to-day. Such a carbon atom is known as an "asymmetric carbon atom," and thus arose the theory of the "asymmetric tetrahedral carbon atom," which has been the philosophy of organic chemistry for the past thirty-five years, and the guiding thought in practically all of the best work in organic chemistry from 1874 to the present time.

The second great work of Van't Hoff had also to do primarily with the chemistry of carbon. In 1867 the Norwegian physicist, Guldberg, and his son-in-law Waage, the chemist, both of Christiania, announced the law of the effect of mass or quantity on chemical reaction—the law of mass action. This was published in the "Announcements" of the University of Christiania, and very little attention was paid to it for some time. Guldberg and Waage applied their law to comparatively few reactions.

Van't Hoff, shortly after the publication of his brief paper of eleven pages in Dutch, on "The Arrangement of the Atoms in Space," took up experimentally the study of the velocities of chemical reactions and the conditions of chemical equilibria, from the standpoint of the law of mass action. He, his assistants and students, carried out an elaborate series of investigations in which the law of mass action was applied to a large number of chemical reactions, and shown to hold. The results of this work were published in French, under the French equivalent of "Studies in Chemical Dynamics." In this work the whole subject of chemical dynamics and chemical equilibrium was placed upon a scientific basis, and for the first time.

The third and greatest work of Van't Hoff had to with the relation between solutions and gases. Through his colleague—the botanist, De Vries, the attention of Van't Hoff was called to the osmotic pressure measurements that had been made by the botanist Wilhelm Pfeffer. A comparison of the results obtained by Pfeffer with the gas pressures exerted by gases containing the same number of gaseous molecules in a given volume that the solution contained dissolved molecules in the same volume, showed that the gas-pressure was exactly equal to the osmotic pressure—in a word, the laws of gas-pressure apply to the osmotic pressure of solutions.

Van't Hoff showed that the laws of gas-pressure apply to the osmotic pressure of solutions of non-electrolytes, *i. e.*, those substances whose aqueous solutions do not conduct the current. He also pointed out that the laws of gas-pressure do not apply to the osmotic pressure of a single electrolyte—a single acid, base or salt. Arrhenius explained the apparent discrepancy in the case of electrolytes by means of the theory of electrolytic dissociation, which says that acids, bases and salts in aqueous solution are broken down into charged parts or ions.

The question arises why is it so important to have shown that the laws of gas-pressure apply to the osmotic pressure of solutions? We know more about matter in the gaseous state than in any other state of aggregation. We can deal with gases from the standpoint of the only exact branch of science—mathematical physics—and Van't Hoff showed that we can deal with solutions in the same manner.

This raises the further question why is it so important to have a satisfactory theory as to the nature of solutions? A moment's thought will furnish the answer. The whole science of chemistry is a branch of the science of solutions. Similarly, the biological sciences are dependent upon solution for their existence, and geology, in dealing both with the sedimentary and the igneous rocks, is vitally concerned with solution in the broader sense of that term. There are, then, few branches of natural science that are not dependent upon solution for their existence.

Van't Hoff made a number of other contributions to science, second in importance only to those named above. He told us what is meant by "Solid Solutions." His last work was an experimental study of the conditions under which the great salt beds at Stassfurth were laid down from a desiccating inland sea.

Van't Hoff published a number of books on physical chemistry but it would lead us too far here to discuss them in any detail.

The writer knew Van't Hoff in the relation of student to teacher. He was one of the most modest, frank, honest and unselfish of men. He lived to see his work properly understood and appreciated. He was elected a member of most of the learned societies and academies in the world. He was awarded the first Nobel prize in chemistry in 1901.

The name of Van't Hoff will undoubtedly go down in the history of science along with those of the very greatest—with Maxwell and Sir J. J. Thomson; with Laplace and Pasteur, and with Helmholtz and Lorentz.

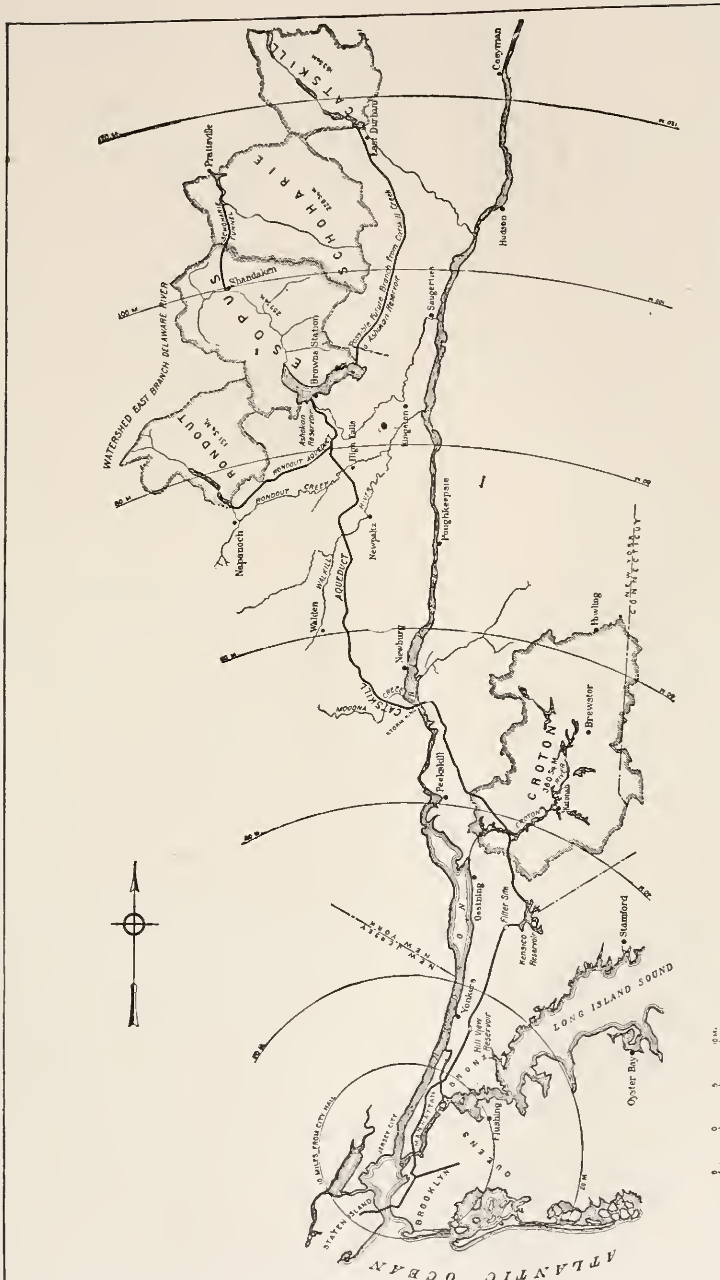
THE PROGRESS OF SCIENCE

THE CATSKILL AQUEDUCT

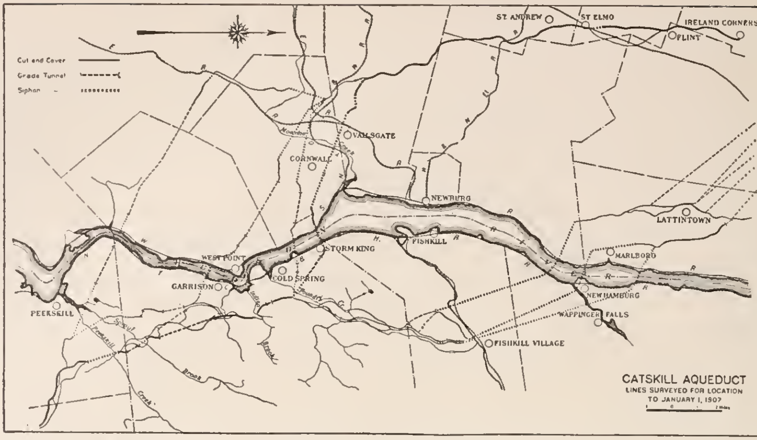
The supply of water for New York City is an engineering and economic problem of the greatest possible importance. The supply from the Croton watershed is at present just about equal to the consumption; if the rainfall during the present year should be small, there is danger lest there be an actual water famine in New York City, the harmful results of which would be almost incalculable. The consumption could be considerably lessened by requiring meters in each house measuring the amount of water used, and it would doubtless be desirable to introduce this system, though it would not give permanent relief. The average daily consumption of Croton water in New York City is over 350,000,000 gallons and the increasing population causes an annual increase of fifteen million gallons a day. Unless an interstate agreement could have been made by which water should have been obtained from Connecticut, the Catskill region is the only source that will give an adequate supply for a long period of years. The engineering problems of bringing the water a hundred miles from the Catskill Mountains are of great magnitude; the construction of the aqueduct is nearly equal to that of the Panama canal in difficulty and in cost.

The geology of the region and to a large extent the engineering problems are reviewed in a bulletin issued by the New York Education Department and prepared by Professor Charles P. Berkey, of Columbia University. The facts and illustrations for this note are taken from this report. The surface of the Ashokan reservoir in the Catskills will be 590 feet above the sea, and the High View reservoir within the limits of New York City will have an elevation of 295 feet. The length of the aqueduct between the two reservoirs will be approximately 92 miles and the main distributing conduit in

A View of the Catskill Mountains, looking across the Beaverkill basin which is to form a part of Ashokan Reservoir.



CATSKILL WATERSHEDS AND AQUEDUCT



OUTLINE MAP SHOWING ALTERNATIVE LINES STUDIED AS POSSIBLE CROSSINGS OF THE HUDSON RIVER.

New York City will be eighteen miles long. The Ashokan reservoir is at a sufficient elevation to permit water to flow down to the Hill View reservoir, but a number of valleys and streams must be crossed, the most striking, from the point of view of the outsider at least, being the gorge of the Hudson River. More than two hundred borings were made at various points, and it was finally decided to construct the aqueduct under the Hudson between Storm King and Breakneck mountains at the north entrance to the Highlands.

It would be possible to bring the water in iron pipes through the mud and silt, as has been done in the case of the Pennsylvania Railway in New York City, but a tunnel through the rock will give great strength and permanence. The accompanying illustration shows the borings which have been made at Storm King, revealing the extraordinary depth of the Hudson gorge. It has been known through the maps of the U. S. Coast and Geodetic Survey that the Hudson River is continued by a submerged gorge more a hundred miles across the continental shelf to the deep sea. This gorge at its deepest part is 3,800 feet in depth, and must apparently have been formed

GENERAL LOCATION MAP OF THE SOUTHERN AQUEDUCT AND ASSOCIATED PARTS OF THE CATSKILL SUPPLY.

A Composite Diagrammatic Cross Section of the Hudson Gorge at the Storm King Crossing, showing the method of making the vertical borings, the direction of the first two inclined borings, the positions of the shafts and the extent of explorations. (Adapted from drawings of the Board of Water Supply.)

during an epoch of great continental elevation. The borings in the Highlands have been carried to a depth of 750 feet without reaching the bottom. This is more than twice as great a depth as has been found at any other point either above or below, though even at Pegg's Point and at New York City it is possible that there is a narrower gorge in the middle of the river. The great width and depth of this gorge must have been due to glacial erosion when a stream of ice was forced down from the wide bay that then existed north of the mountains. The syphon tunnel under the Hudson is only one of a number of great syphons and aqueducts that must be constructed between the Catskills and New York City. Owing to the present

Cathedral Gorge, a postglacial entrenchment of Esopus Creek at the Tongore site. The preglacial gorge lies at the north side of the valley buried beneath 250 feet of drift. (Photograph by Board of Water Supply.)

need of the watershed, it is proposed to develop at first only the Esopus watershed by the construction of the great Ashokan dam at Olive Bridge and to carry the water to the present Croton system, the aqueducts of which are somewhat in excess of the Croton supply in dry years. It is hoped that this part of the undertaking may be completed within three years.

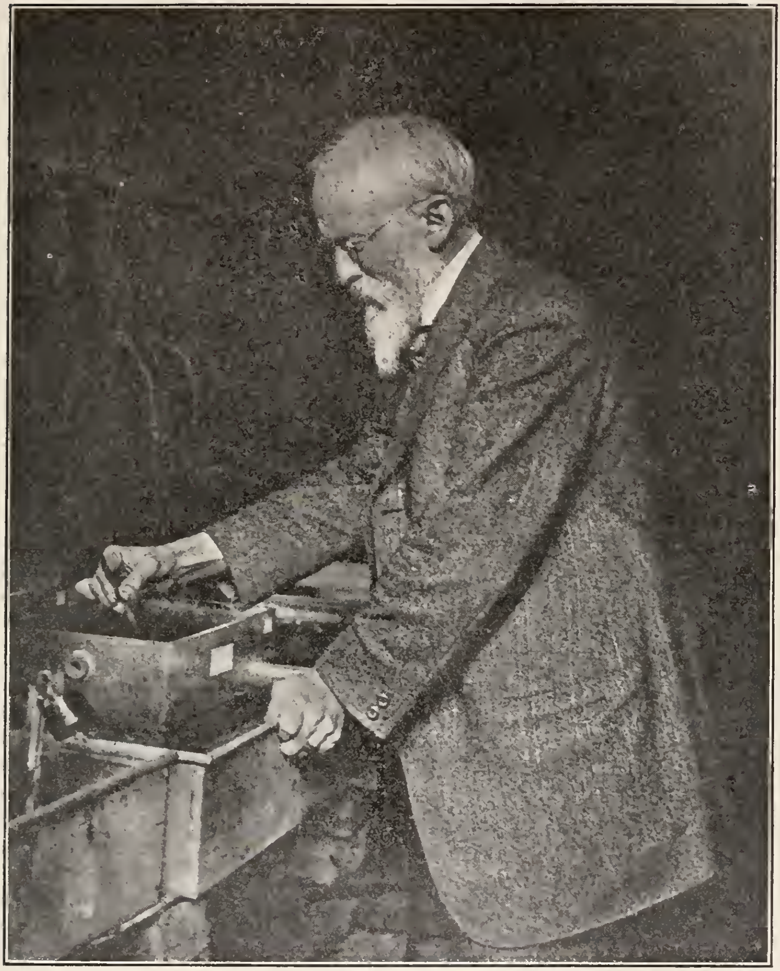
THE AMHERST IDEA

The class of 1885 of Amherst College at its twenty-fifth reunion a year ago appointed a committee to present to the trustees an address on the future development of the college. It is an interesting fact that the alumni of a college should concern themselves with scholarship rather than with athletics, and the address is a document of such considerable moment that it has attracted wide attention. The committee signing the report points out that the conditions for a college such as Amherst have changed in the course of the past twenty-five years. The great universities, especially the state universities, take students from the high school and graduate them prepared for a technical career. A college such as Amherst can not compete with these institutions. According to the committee it has or should have other objects. It should demand a preparation not within the tendencies of the high schools, and give a course which postpones preparation for a profession. Amherst should retain, or return to, a liberal or classical education and confine its work to this. The committee makes to the trustees five definite propositions:

1. That the instruction given at Amherst College be a modified classical course.
2. That the degree of bachelor of science be abolished.
3. That the college adopt the deliberate policy of devoting all its means to the indefinite increase of teachers' salaries.
4. That the number of students attending the college be limited.
5. That entrance be permitted only by competitive examination.

The committee does not make clear just what a modified classical course should be. They say that all would agree that some knowledge of science is part of a liberal education and that no one would advocate the adoption of the unchanged classical course of fifty years ago. They also say that a classical education is a training in civics, the history of government, etc. The difficulty is that if students are to be thoroughly trained in Latin and Greek, they must specialize quite as much as students preparing for the professions. Now that we have admirable technological schools, it would apparently be desirable to have schools that would specialize to the same extent in the languages, on the one hand, and in history and political science, on the other. This is not because, as the committee argues, technical education teaches devices instead of principles, and is one of the causes of the increased excitability of American politics. This is little short of nonsense. But it would be desirable for one college to give a thorough classical education for the training of scholars in this direction and as a basis for work in literature, in law and in other professions. It is an advantage for men to enter on their professions with diverse training in order that they may specialize in different directions. Such a college should have a graduate department, which the Amherst committee apparently regards as superfluous, in order to maintain the scholarship both of its professors and of its students.

This, however, is presumably not at all what is wanted by the committee; it would let Amherst College give a liberal education on the lines, for example, advocated by President Lowell, teaching those things which a cultivated gentleman should know. If such an education is desirable there is much to be said for giving it at a small college rather than in a great university. If a college is limited to some three hundred students, it is possible for all the students to attend the same courses, to know each other and all the



Dr. Richard Hertwig

This portrait of the eminent zoologist of the University of Munich shows him at the age of sixty years, when a "Festschrift" has been prepared in his honor by his former students.

professors, and for the professors in turn to teach and know all the students, and to feel personally responsible for the work of the whole institution. It is, however, somewhat difficult to decide how the number of students shall be limited. According to the committee it should be done by competitive examinations. This, however, is a doubtful expedient, as the preparation for a competitive examination is not necessarily the best educational method, and young students who can pass such an examination with the highest grades are not always those who will be successful in their later work. It would apparently be a better plan to admit all promising students and to drop a considerable percentage at the close of the first year. Under these conditions students are likely to work well at the start, whereas if they pass a competitive examination of which they do not particularly approve they may feel that they deserve some relaxation. It would probably be desirable for Amherst to decrease the number of students by giving up the degree of B.S., unless the college is prepared to offer adequate courses in the natural and exact science. The degree of B.S. at certain colleges is scarcely more reputable than the degree of B.E.—bachelor of the elements—which is given by one college to the students who fail to obtain any other degree.

The third recommendation of the committee will certainly be approved by college professors. The maximum salary at Amherst is $3,000 and the committee finds that, on the average, professors spend a thousand dollars in excess of their salary. This fact is in itself not significant, for it might mean that one or two professors had large incomes. To make the figures of value the committee should give the number of professors who spend on their living more than three thousand dollars. It is, however, well known that college and university professors receive relatively smaller salaries than men at the head of the other professions, and if a college such as Amherst wishes to obtain and retain for its faculty men of the highest ability, the salaries must be increased.

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. Samuel H. Scudder, of Cambridge, eminent for his contributions to entomology; of Dr. Stanford Emerson Chaillé, for forty-one years professor of physiology and pathological anatomy in the medical department of Tulane University; of Dr. Edward Burnett Vorhees, professor of agriculture at Rutgers College and director of the New Jersey Agricultural Experiment Station; of Professor William Russell Dudley, professor of botany in Stanford University; of Nathaniel Wright Lord, professor of mineralogy and metallurgy in the Ohio State University; of Mrs. Williamina Paton Fleming, curator of astronomical photographs in the Harvard College Observatory, and of Dr. N. Story Maskelyne, from 1856 to 1895 professor of mineralogy at Oxford.

Professor E. C. Pickering, director of the Harvard College Observatory, has been created knight of the Prussian order Pour le mérite. Simon Newcomb and Alexander Agassiz are the only other American men of science on whom this honor has been conferred.—At its annual meeting the American Academy of Arts and Sciences voted to award the Rumford premium to Professor James Mason Crafts "for his investigations in high temperature thermometry and the exact determination of new fixed reference points on the thermometric scale."

During his recent visit to Washington at the time of the annual meeting of the National Academy of Sciences, Sir John Murray presented a fund of six thousand dollars to the academy for the purpose of founding an Alexander Agassiz gold medal which shall be awarded to scientific men in any part of the world for original contributions to the science of oceanography.

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THE SIGNIFICANCE OF TROPISMS FOR PSYCHOLOGY[1]

BY PROFESSOR JACQUES LOEB
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I

THE scientific analysis of psychical phenomena must, I believe, aim to explain these phenomena according to laws of physical chemistry. I know very well that many people would hold that even a complete physico-chemical analysis of all psychic phenomena must still leave the "truly psychical" unexplained. I do not agree with such an opinion, but as we are to-day still very far from the ideal of a complete physico-chemical analysis of psychical phenomena, there is nothing to be gained by quarrelling about just how much scientific illumination and satisfaction we shall attain when that goal is once reached. On the second point, however, a general agreement may be reached, namely, first, that we must undertake and carry out a physico-chemical analysis of psychical phenomena; and, second, that for such an analysis the same principles of investigation are required as for the physico-chemical analysis of the very much simpler processes in inanimate nature.

Twenty-two years ago I came to the conclusion that what we call "will" in many lower animals is nothing but the phenomena of tropisms well known in plants, especially through the work of Sachs. In a series of articles, of which the first two appeared[2] in January, 1888, I have tried to establish this view, and I will now summarize the facts briefly, and try to do away with some of the difficulties which zoologists and psychologists have experienced in applying my theories. To my mind the essential value of my theory lies in the preparation

[1] Lecture given at the Sixth International Psychological Congress at Geneva, 1909. Published by Johann Ambrosius Barth, Leipzig, 1909. (Translated by Grace B. Watkinson, New York, February, 1911.)

[2] Loeb, *Sitzungsber. der Würzburger Physik.-Med. Gesellsch.*, 1888.

it gives for the application of the law of mass action (and other physico-chemical laws) to phenomena which usually form the material for psychological speculation. To make possible a better understanding of my lecture, let me mention briefly how I came to hold the views set forth here.

The writings of the metaphysicians on the will in nature led me to an experimental analysis of the nature of will. When in my first years at the university Munk's investigations on the cerebral cortex fell into my hands I believed that here was a starting point toward my goal. Munk stated that he had succeeded in proving that every memory image in a dog's brain is localized in a particular cell or group of cells and that any one of these memory images can be extirpated at will. Five years of experiments later with extirpations in the cerebral cortex proved to me without doubt that Munk had become the victim of an error and that the method of cerebral operations can really give only data concerning the nerve connections in the central nervous system but teach practically nothing about the dynamics of brain processes.

A better way seemed to lie in the comparative psychology of the lower animals in which the memory apparatus is developed but slightly or not at all. It seemed to me that some day it must become possible to trace the apparently random movements of animals back to general laws, just as definitely as it has been done for the movements of the planets, and that the word "animal will" is only the expression of our ignorance of the forces which prescribe for animals the direction of their apparently spontaneous movements just as unequivocally as gravity prescribes the movements of the planets. For if a savage could directly observe the movement of the planets and should begin to ponder over it, he would probably come to the conclusion that a "will action" guides the movements of the planets, just as a chance observer is inclined to assume that "will" causes animals to move in a given direction.

The scientific solution of the problem of will seemed to consist in finding the forces which unequivocally determine the movements of animals, and in discovering the laws according to which these forces act. Experimentally, the solution of the problem of will must take the form of forcing, by external means, any number of individuals of a given kind of animal to move in a definite direction by means of their locomotor apparatus. Only if this succeeds have we the right to assume that we know the force which under certain conditions seems to a layman to be the will of the animal. But if only a part of the number moves in this definite direction and another does not, then we have not succeeded in finding the force which in a given case determines unequivocally the direction of movement.

One other point should be observed. If a sparrow flies down from a roof to a seed lying in the street, we speak of an act of will, but if a dead sparrow falls from the roof upon the seed this does not appear to us to be an act of will. In the latter case purely physical forces are concerned, while in the former chemical reactions are also taking place in the sense organs, nerves and muscles of the animal. We speak of an act of will, only when this latter complex, that is, the natural movement of locomotion, plays its part also, and it is only with this sort of reactions that we have to deal in the psychology of the will.

II

Some experiments on winged plant lice may serve as an introduction to these methods of definitely prescribing to animals the direction of their progressive movements.

In order to obtain the material, potted rose-bushes or cinerarias thickly infected with plant lice are brought into a room and placed in front of a closed window. If the plants are allowed to dry out, the aphids, previously wingless, change into winged insects. After this metamorphosis the animals leave the plants, fly to the window and there creep upward on the glass. They can then be easily collected by holding a test-tube underneath and touching one animal at a time from above with a pen or scalpal; the animals then drop into the test-tube. In this way a sufficiently large number, perhaps twenty-five or fifty suitable subjects for the experiment, may be quickly obtained. With these animals it may be demonstrated that the direction of their movement toward the light is definitely determined—provided that the animals are healthy and that the light is not too weak. The experiment is arranged so that only a single source of light, *e. g.*, artificial light, is used.

The animals place themselves with their heads toward the source of light and move in as direct a line as the imperfectness of their locomotor apparatus allows, toward it. If they are in a test-tube they go as far toward the source of light as their prison allows. When they reach that end of the test-tube which is directed toward the source of light, they remain there, stationary, in a closely crowded mass. If the test-tube is turned around 180° the animals again go straight toward the source of light until the interference of the glass stops their further progressive movements.[3] It can be demonstrated in these animals that the direction of their progressive movement is just as unequivocally governed by the source of light as the direction of the movement of the planets is determined by the force of gravity.

The theory of the compulsory movements of aphids under the influence of light is as follows: Two factors govern the progressive move-

[3] Loeb, "Der Heliotropismus der Tiere und seine Übereinstimmung mit dem Heliotropismus der Pflanzen," Würzburg, 1890 (Erschienen, 1889).

ments of the animals under these conditions; one is the symmetrical structure of the animal, and the second is the photochemical action of light. We will consider the two separately. In regard to the photochemical action of light, we know to-day that a great many chemical reactions of organic bodies are accelerated by light. Especially is this true of oxidations.[4] The mass of facts presented to us here concerning this relatively young branch of physical chemistry is already so great that we have the right to assume that the determining action of light upon animals and plants is in its last analysis due to the fact that the rate of certain chemical reactions in the cells of the retina or of other photosensitive regions of the organisms is modified by light; with increasing intensity of light the rate of certain chemical reactions, for instance, oxidation, increases according to a definite law, namely, the law of Bunsen and Roscoe.

The second factor is the symmetrical structure of the animal. As expressed in the gross anatomy of the animal this is shown by the well-known fact that the right and left halves of the body are symmetrical. But it is my belief that such a symmetry exists in a chemical sense as well as in an anatomical sense—by which I mean that symmetrical regions of the body are chemically identical and have the same metabolism, while non-symmetrical regions of the body are chemically different, and in general have a quantitatively or qualitatively different metabolism. In order to illustrate this difference it is only necessary to point out that the two retinas, which are certainly symmetrical, have an identical metabolism, while a region of the skin which is not symmetrical with the retina has a different metabolism. The individual points on the retina are also chemically unlike. The observations upon visual purple, the differences in the color-sensitiveness of the fovea centralis, and the peripheral parts of the retina indicate that the points of symmetry of the two retinas are chemically like, but the non-symmetrical points chemically unlike.

Now if an unequal amount of light falls upon the two retinas, the photo-chemical reactions in the retina which receives more light will also be more accelerated than in the other. The same thing naturally holds true for every other pair of symmetrical photosensitive surface elements. For it should be mentioned just here that photochemical substances are not only found in the eyes, but also in other places on the outer surface of many animals. In planarians, as my experiments and those of Parker have shown, not only the eyes, but also other places on the skin, are photosensitive. But if more light falls upon one retina than upon the other, the chemical reactions, for instance, the or-

[4] Luther, "Die Aufgaben der Photochemie," Leipzig, 1905. C. Neuberg, *Biochem. Zeitschr.*, Bd. 13, S. 305, 1908. Loeb, "Vorlesungen über die Dynamik der Lebenserscheinungen," Leipzig, 1906. In addition, the work of Ciamician, as also Wolfgang Ostwald (*Biochem. Zeitschr.*, 1907).

ganic oxidation, will also be more accelerated in one retina than in the other, and accordingly more intense chemical changes will take place in one optic nerve than in the other. S. S. Maxwell and C. D. Snyder have demonstrated, independently, that the rate of the nerve impulse has a temperature coefficient of the order of magnitude which is characteristic for chemical reactions. According to this we must conclude that when two retinas (or other points of symmetry) are illuminated with unequal intensity, chemical processes, also of unequal intensity, take place in the two optic nerves (or the sensory nerves of the two points). This inequality of chemical processes passes from the sensory to the motor nerves and eventually into the muscles connected with them. We conclude from this that with equal illumination of both retinas the symmetrical groups of muscles of both halves of the body will receive equal chemical stimuli and thus reach equal states of contraction, while when the rate of reaction is unequal, the symmetrical muscles on one side of the body come into stronger action than those on the other side. The result of such an inequality of action of symmetrical muscles of both halves of the body is a change in the direction of movement on the part of the animal.

This change in the direction of movement can result either in a turning of the head toward the source of light and the accompanying movement of the whole animal toward the source of light, or in a turning of the head in the opposite direction and the accompanying movement of the whole animal in the opposite direction. In order to show that the choice between the two possibilities has to do with purely physico-chemical conditions, we should have to discuss, one by one, a whole series of topics upon the physiology of the central nervous system. It may suffice to call to mind briefly first that the structure of the central nervous system is segmental and that the head segments generally determine[5] the behavior of the other segments with their accessory parts; and secondly that chemical processes in any single element can cause an increase in the tonus of certain muscle groups as well as causing just the opposite effect under other conditions.

In the winged aphids the relations are as follows: Suppose that a single source of light is present and that the light strikes the animal from one side. As a consequence the activity of those muscles which turn the head or body of the animal towards the source of light will be increased.[6] As a result the head, and with it the whole body of the

[5] Loeb, "Comparative Physiology of the Brain and Comparative Psychology," New York and London, 1900.

[6] If two equally powerful sources of light are present at equal distances from the animal, the animal will move in a line at right angles to a line connecting the two sources of light, because in this case both eyes are similarly influenced by the light. Herein, as Bohn has rightly said, the machine-like heliotropic reaction of animals differs from the movement of a human being

animal, is turned toward the source of light. As soon as this happens, the two retinas become illuminated equally. There is therefore no longer any cause for the animal to turn in one direction or the other. It is thus automatically guided toward the source of light. In this instance the will of the animal which determines the direction of its movement is light, just as it is gravity in the case of a falling stone or the movement of a planet. Only the action of gravity upon the direction of movement of the falling stone is direct, while the action of light upon the direction of movement of the aphids is indirect, inasmuch as the animal only by means of an acceleration of photochemical reactions is caused to move in a definite direction.

We will now designate as positively heliotropic those animals which are forced to turn the head or the parts of the body which are foremost during locomotion toward the source of light, and as negatively heliotropic those animals which are oriented in the opposite direction.

The aphids serve here only as an example. The same phenomena of positive heliotropism may be demonstrated with equal precision in a great many animals, vertebrates as well as invertebrates, for instance in young fishes. We can not, of course, give an account of all these cases here. The reader who is interested in them must look into the voluminous literature upon this subject.[7]

III

The winged aphids can serve as an example, because in their case the above-mentioned requirement is fulfilled, namely, that *all* individuals, without exception, move toward the light. For mechanistic science it is a methodological postulate that the same law applies without exception, or that a sufficient reason must be given in case of an exception. But it was soon found, as might be expected, that not all organisms in their natural condition are equally suitable for these experiments. Many animals show no heliotropism at all; many show only a slight reaction, while others show it to as pronounced a degree as do the winged aphids. The problem therefore presented itself of making artificially heliotropic those animals which show no positive heliotropism. Such attempts give us a broad insight into the mechanism of acts of will. If small crustaceans of a fresh-water pond or lake are taken with a plankton net at noon-time or in the afternoon and placed in an aquarium which is illuminated from one side only, it is generally found that these animals move about in the vessel pretty much at random and distribute themselves irregularly. Some seem to go more toward the

toward one of two sources of light, the movement in the latter case not being determined by heliotropism.

[7] Heliotropism is unusually common, namely, among the larvæ of marine animals and insects, but also not lacking in sexually mature individuals.

lighted side, others in the opposite direction, and the majority perhaps pay no attention to the light.

This condition changes instantly if we add to the water some acid, preferably carbonic acid, which easily penetrates the cells. This is done by slowly adding to every 50 c.cm. of the fresh water a few cubic centimeters of water charged with carbondioxide. If the correct amount of carbonic acid is added all the individuals become actively positively heliotropic in a few moments and they move in as straight a line as the primitiveness of their swimming movements permits, toward the source of light, and remain there closely crowded together on the lighted side of the vessel. If the vessel is turned around 180°, they go directly back again to the lighted side of the vessel. Every other acid acts like carbonic acid and alcohol acts in the same manner, only more feebly and much more slowly. Animals which were previously indifferent to light become, under carbonic acid treatment, complete slaves of the light.[8]

How does the acid produce this result? We will assume that it acts as a sensitizer. The light produces chemical changes, for instance, oxidation on the surface of the animal, especially in the eye, as was suggested in the case of the aphids. The mass of photochemical substance which is acted upon by the light is often relatively small, so that even when the light strikes the crustacean (copepod) on one side only, the difference in the chemical changes on the two sides of the body remains still too small to call forth a difference in tension or action, in the muscles of the two sides of the body, sufficient to turn the animal toward the source of light. But if we add an acid this could act as a catalyzer, as, for instance, in the *catalysis of esters.* In the *catalysis of esters,* the acid acts, according to Stieglitz, only to the extent of increasing the active mass of the substance which undergoes a chemical change. In order to provisionally fix our ideas, we will assume that the acid makes the animal more strongly positively heliotropic by increasing the active mass of the photosensitive substance. By this means it becomes possible for the same intensity of light which before produced no heliotropic reaction now to cause a very pronounced positively heliotropic reaction; because if now the animal is struck on one side only by the light, the difference in the reaction product in both retinæ becomes rapidly great enough to cause automatically a difference in the action of the muscles of both sides of the body and a turning of the head towards the source of light.

A second consideration must also be mentioned here. In certain forms, for instance, in daphnia and in certain marine copepods, a decrease in temperature also increases the tendency to positive heliotropism. If the mere addition of acid is not sufficient to make the

[8] Loeb, *Pflügers Archiv,* Bd. 115, S. 564, 1906.

daphnia positively heliotropic, this may often be accomplished by simultaneously reducing the temperature. From the physico-chemical standpoint we must assume that likewise in the dark, at the ordinary temperature, the photosensitive substance is destroyed so rapidly that its active mass is generally rather too low to cause a heliotropic reaction. By reducing the temperature the rate of decomposition of the photosensitive substance is decreased more than the rate of its formations.

This illustration may suffice, under the limitations of the space allowed us, to indicate how the facts in this field might be correlated when viewed from the standpoint of physical chemistry.

IV

The animals which are strongly positive heliotropic and those animals which do not react at all to light offer the observer no difficulties. Nevertheless, some zoologists, apparently not very familiar with the laws of physical chemistry, seem to have found difficulty in explaining the behavior of those animals which come between the two extremes. For instance, one writer has asserted that with greater intensity of light the laws of heliotropic orientation hold good, while with a lessened light-intensity the animals react to light by the method of "trial and error." From a chemical standpoint the behavior of animals at low intensity is easily to be understood. If a positively heliotropic animal is illuminated from one side a compulsory turning of the head toward the source of light occurs only when the difference in the rate of certain photochemical reactions in the two eyes reaches a certain value. If the intensity of the light is sufficient and the active mass of photochemical substance in the animal great enough, it is only a short time, for instance, the fraction of a second, before the difference in the mass of the reaction products formed on the two sides of the animal reaches the value necessary for the compulsory turning of the head toward the source of light. In this case the animal is a slave of the light; in other words, it has hardly time to deviate from the direction of the light rays; for if it turns the head even for the fraction of a second from the direction of the light rays, the difference in the photochemical reaction-products in the two retinas becomes so great that the head is at once automatically turned back toward the source of light. But if the intensity of the light is lessened (or the photosensitiveness of the animal lessened) the animal may deviate for a longer period from the direction of the light rays. Such animals do eventually reach the lighted side of the vessel, but they no longer go straight toward it, but move instead in zig-zag lines or very irregularly. It is, therefore not a case of a qualitative, but of a quantitative, difference in the behavior of heliotropic animals under greater or lesser illumination, and it is therefore erroneous to assert that heliotropism determines the movement of animals toward the source of light only under strong illumination, but that under weaker illumination an essentially different condition exists.

Still another point is to be considered. We have seen that acid increases the sensitiveness of certain animals to light and probably, as we assume, by increasing the active mass of the photochemical substance. Now every animal is continually producing acids in its cells, especially carbonic acid and lactic acid. It probably produces also substances which could have the opposite effect and which decrease the heliotropic sensitiveness of the animals. Fluctuations in the rate of production of these substances will also produce fluctuations in the heliotropic sensitiveness of the animal. Now if, for instance, the active mass of the photosensitive substance in a copepod is relatively small, a temporary increase in the production of carbonic acid can increase the photosensitiveness of the animal sufficiently for it to move for the period of a few seconds directly toward the source of light. Later the production of carbonic acid decreases and the animal again becomes indifferent to light and can move in any other direction. Then the production of carbonic acid increases again and the animal goes again, for a short time, toward the light. Such animals finally gather at the lighted side of the vessel because the algebraic sum of the movements in the other directions becomes zero according to the law of chance. But it is plain that such animals do not reach the source of light by a straight path. A writer who is not trained to interpret the variations in the behavior of such an animal chemically and physiologically, can naturally give no explanation of their significance. If he is forced to find an explanation he will wind up at the method of "trial and error" which is no more chemical nor scientific than the explanations of metaphysicians in general.

Some authors have, it seems, worked only with animals which were not pronouncedly heliotropic and the photo-sensitiveness of which wavered about the threshold of stimulation in the manner described above. A writer trained in physical chemistry would have understood that such animals are unsuitable for experiments in heliotropism and that it is necessary to first increase their photo-sensitiveness if the laws of the action of light upon them are to be investigated.

I also believe that observations upon animals which are not sufficiently photo-sensitive have caused many writers to assert that heliotropic animals do not place themselves directly in the line of the rays of light,[9] but that they first have to learn the right orientation. But a very striking experiment contradicts this assertion. The larvæ of *Balanus perforatus* develop entirely in the dark. If the ovary filled with mature larvæ is, in the dark, placed in a watch crystal filled with sea water, the larvæ emerge at once and, if they are brought into the

[9] Provided that only a single source of light is present.

light, they move at once to the side of the watch crystal nearest to the window. They were, therefore, pronouncedly positively heliotropic before they came under the influence of the light.

In experiments with winged aphids I often found that after having gone through the heliotropic reactions a few times they react much more quickly to light than at the beginning. This might be interpreted as a case of "learning." In so far as it is not a case of a lessening of the stickiness of the feet or the removal of some other purely mechanical factor which retards the rate of movement, it may be brought about by the carbonic or lactic acids produced through the muscular activity.[10]

V

As far back as twenty years ago I pointed out that the photo-sensitiveness of an animal is different in different physiological conditions and that, therefore, under natural conditions, heliotropism is found often only in certain developmental stages, or in certain physiological states of an animal. I have already mentioned that in the aphids distinct heliotropic reactions may only be expected when the animals have developed wings and left the plant. The influence of the chemical changes which take place in animals upon heliotropism is much more distinct in the larvæ of *Porthesia chrysorrhœa.* The larvæ hatch from the eggs in the fall and, as young larvæ, hibernate in a nest. The rising temperature in the spring drives them out of the nest and they can be driven out of the nest in winter also by an increase in temperature. When they are driven out of the nest in this condition they are strongly positively heliotropic and I have never found in natural surroundings any animals whose heliotropic sensitiveness was more pronounced than it is in the young larvæ of Chrysorrhea under these conditions. But as soon as the animals have once eaten the positive heliotropism disappears and does not return if they are again allowed to become hungry.[11] In this case it is clear that the chemical changes connected with nutrition directly or indirectly lead to a permanent diminution or disappearance of the photochemical reaction. In ants and bees the influence of substances from the sexual organs seems to be the determining factor in the production of positive heliotropism. The ant workers show no heliotropic reactions while in the males and females, at the time of sexual maturity, a distinct positive heliotropism develops, the intensity of which continues to increase.

[10] The phenomenon of "steps" ("Treppe") upon stimulation of a muscle is ascribed, probably rightly, also to the formation of acid. The phenomenon of "steps," that is, the increase of the amount of contraction with every new stimulus is, however, comparable to or identical with the increase in the rate of reactions in the experiments described here.

[11] Loeb, *l. c.*, p. 24. (This latter fact has been overlooked by several writers.)

According to Kellogg the case of the bees is similar. It is a well known fact that during sexual maturity special substances are formed which influence various organs. For instance, Leo Loeb has found that the substances which are set free by the bursting of an egg follicle cause a special sensitiveness in the non-pregnant uterus, so that every mechanical stimulus causes the latter to form a decidua. In this way he could cause the formation of any number of deciduæ in non-pregnant uteri, while without the follicle substance the uterus did not react in this manner.

It is a common phenomenon that animals in certain larval stages are positively heliotropic, while in others they are not sensitive to light or are even negatively heliotropic. In order to save time I will not now discuss further these facts which are easily comprehensible in the light of what has been said and I refer the readers to my earlier papers.

This change in the heliotropic sensitiveness, produced by certain metabolic products in the animal body is of great biological significance. I have already shown that it even serves to save the lives of the above-mentioned young larvæ of Chrysorrhœa. When the young larvæ are awakened from their winter sleep by the spring sunshine they are actively positively heliotropic. The positive heliotropism leaves them no freedom of movement, but forces them to creep (eindeutig) straight upward to the top of a tree or branch. Here they find the first buds. In this way the heliotropism guides them to their food. Should they now remain positively heliotropic they would be held fast on the ends of the twigs and would starve to death. But we have already mentioned that after they have eaten they lose the positive heliotropism once more. They can now creep downwards, and the restlessness which is characteristic of so many animals[12] forces them to creep downwards until they reach a new leaf, the odor or tactile stimulus of which stops the progressive movement of the machine and sets in motion further eating activity.

The fact that ants and bees become positively heliotropic at the time of sexual maturity plays an important rôle in the vital economy of these creatures. As is well known, the mating of these insects takes place during flights, the so-called nuptial flight. Now I have watched and found that among the male and female ants of a single nest the heliotropic sensitiveness increases steadily up to the time of the nuptial flights and that the direction of their nuptial flights follows the direction of the rays of the sun in the afternoon. I gained the impression that this nuptial flight is merely the consequence of a very highly developed heliotropic sensitiveness. The case must be similar among the bees according to the following experiment described by Kellogg. The

[12] The physico-chemical cause of this "restlessness" which is noticeable in many insects and crustaceans is at present unknown.

bees were ready to swarm out of the opening of the box used for the experiment when he suddenly removed the dark covering of the box so that the light now entered it from above. The heliotropic sensitiveness of the animals was so great that they crept upward within the box, following the direction of the light rays and were not able to make the nuptial flight. Thus, according to these observations the bees at the time of the nuptial flight are positively heliotropic machines.

These observations may serve as examples of the way in which analyses of the vital phenomena of certain animals show tropisms to be elements of these phenomena. Many observations of a similar nature are found in the papers of George Bohn, Parker, Rádl[13] and myself. What appear to us upon incomplete analysis as acts of will or instinct prove upon more careful analysis, in a series of cases, to be tropisms, the theories of which we have explained in the foregoing pages.

VI

Under the influence of the theory of natural selection the view has been accepted by many zoologists and psychologists that everything which an animal does is for its best interest. But now the exact doctrine of heredity, founded by Mendel and advanced to the position of a systematic science in 1900, reduces this false idea to its proper value. It is only true that species possessing tropisms which would make reproduction and preservation of the species impossible must die out. The opposite view, however, namely, that every reaction or every tropism which an animal possesses is for its interest, or of great benefit to it, is just as incorrect as the view that every structural characteristic of a species must be useful to it.

Galvanotropism illustrates this in a striking manner. If a galvanic current is passed through a trough filled with water, and if animals are placed in this trough it can be observed that an orientation in relation to the direction of the current takes place in many animals and that the organisms move in the direction either of the positive or of the negative current. In this case we speak of galvanotropism. In galvanotropism the current lines or the current curves play the same rôle as the light rays in heliotropism. The explanation is that at those points where the current curves enter the cells[14] a collection of ions takes place which influences the chemical reactions. The number of organisms which show typical galvanotropic reactions is not so large as the number of those which show typical heliotropism. According to my opinion this difference is the result of the physical difference in the action of light and of the electric current. Light acts essentially upon the free surface of the animal, while the electric current affects

[13] Rádl, "Der Phototropismus der Tiere," Leipzig, 1903.

[14] Or where the movement of the ions within the cell is retarded.

all the cells and nerves of the animal. Thus, in general, the action of the current upon the skin becomes complicated and modified by its simultaneous effect upon the nerve branches and upon the central nervous system. The result is thus much more complicated than that of the action of light where essentially only the effect upon the skin and retina is involved. For this reason, a distinct galvanotropism is found more often in organisms with simple structure, as, for instance, in one-celled organisms, than in vertebrates, although it is also demonstrable in the latter.

Galvanotropism is, however, purely a laboratory product. With the exception of a few individuals, which have in recent years fallen into the hands of physiologists who happened to be working on galvanotropism, no animal has ever had the chance to come under the influence of an electric current. And yet galvanotropism is a remarkably common reaction among animals. A more direct contradiction of the view that the reactions of animals are determined by their needs or by natural selection could hardly be found.

One might be led to suppose that galvanotropism and heliotropism are not comparable. They are, however, as a matter of fact, phenomena of the same category with the exception of the aforementioned fact that light acts generally only upon the surface of the skin, while the electric current influences all the cells of the body. As already mentioned, the disturbing complications arising from this latter circumstance disappear for the most part when we work with one-celled organisms, and we should expect that galvanic and heliotropic reactions would more nearly resemble one another in this case, provided that we work with organisms which possess both forms of sensitiveness. And this expectation is fulfilled. The colonial algæ of the species *Volvox* show heliotropism and galvanotropism. The investigations made by Holmes and myself upon heliotropism, as well as those of Bancroft upon the galvanotropism of these organisms, indicate that the mechanism of these reactions in *Volvox* is the same and the degree of determinism of the heliotropic and galvanotropic reactions in *Volvox* is equally great.

Claparède raises the objection that the galvanotropic reactions are purely compulsory, while the heliotropic reactions are governed by the "interest of the animal."[15] Such a view, however, is not supported by the facts. The reason that heliotropism may occasionally, as we have seen, be of use, while galvanotropism has no biological significance, is because the electric current does not exist in nature. It can, however, be shown also that heliotropism is just as useless to many animals as galvanotropism. For instance, I pointed out twenty years ago that some varieties of animals which do not live in the light at all, for

[15] Claparède, "Les tropismes devant la Psychologie," *Journ. f. Psychologie und Neurologie,* Bd. 13, S. 150, 1908.

instance, the larvæ of the goat moth, which live under the bark of trees, may show positive heliotropism. I found, moreover, that the crab, *Cuma Rathkii,* which lives in the mud of the harbor of Kiel, when brought into the light and removed from the mud shows positive heliotropism. It is, therefore, just as incorrect to assert that the heliotropic reactions are governed by the biological interests of the animal as that this is true for galvanotropism. We must therefore free ourselves at once from the overvaluation of natural selection and accept the consequences of Mendel's theory of heredity, according to which the animal is to be looked upon as an aggregate of independent hereditary qualities.

VII

The attempt has been made to prove that organisms are attuned to a certain intensity of light and so regulate their heliotropism that they invariably reach that intensity of light which is best suited to their well-being. I believe that this is also a case of a suggestion forced upon the investigators by the extreme application of the natural selection theory. I have made experiments upon a large number of animals, but, with a clear arrangement of the physical conditions of the experiment, I have never found a single indication of such an adaptation. In every case it has been shown that positively heliotropic animals are positive with any intensity of light above the threshold. Thus winged plant lice or wingless larvæ of *Chrysorrhœa* or copepods, which have been made heliotropic by acids, go toward the light regardless of whether the source of light is the direct sunlight or reflected light from the sky or weak lamp light, provided that the (threshold) value of intensity of light required for the reaction is passed. Indeed, I have been able to show that positively heliotropic animals also move toward the source of light even if the arrangement is such that by so doing they go from the light into the shadow.[16] A "selection" of a suitable light intensity I have never observed.

What probably lies behind these interpretations of the "selection of suitable light intensity" is the fact that under certain conditions reaction products formed by the photochemical action of light may inhibit the positive heliotropism. I found a very clear instance of this sort in the newly hatched larvæ of *Balanus perforatus,* which are positively heliotropic. If they are placed in the light of a quartz mercury lamp (of Heraus) which is very rich in ultra-violet rays, the positively heliotropic larvæ soon become negatively heliotropic. For these experiments

[16] Quite often without even stopping for a moment. In animals sensitive to differences (see next chapter) a stopping occurs in this experiment in the passing from the light into the shadow, but they go, nevertheless, immediately on in the direction of the source of light. The reader will find a further account of this experiment in my "Vorlesungen über die Dynamik der Lebenserscheinungen."

the larvæ should be placed only in a very shallow depth of sea-water.

Even in a strong light which is not so rich in ultra-violet rays as the light of the mercury lamp, it is sometimes possible to cause positively heliotropic animals to become negatively heliotropic. This is the case, for instance, with the larvæ of *Polygordius.* But it would be wrong in this case to speak of an adaptation of the animal to a certain light intensity. In my opinion it is merely a case where a metabolic product either alters the photochemical action or so influences the central nervous system that even the excitation of the retina by the light weakens the tonus of the muscles, instead of strengthening it.

Some of the other mistakes have perhaps also arisen because the writers worked with complicated experimental conditions instead of with simple ones, for instance, because they used a hollow prism filled with ink in order to produce a gradual decrease in the light intensity. In the semi-darkness thus produced, the intensity of light often remains beneath or near the threshold of stimulation, and the writers fall victims to that class of errors which we have already pointed out in speaking of the influence of lesser intensities of light.

VIII

Heliotropic phenomena are determined by the relative rates of chemical reactions occurring simultaneously in symmetrical surface elements of an animal. There is a second class of phenomena which is determined by a sudden change in the rate of chemical reactions in the same surface elements. Reactions to sudden change of light intensity are shown most clearly in marine tube worms, whose gills are exposed to light. If the light intensity in the aquarium is suddenly diminished the worms withdraw quickly into their tubes. A sudden increase of light intensity has no such effect. With other forms, for instance, with planarians, a sudden decrease of the intensity of the light causes a decrease in movement. Such animals gather chiefly in parts of the space where the light intensity is relatively small. I have designated such reactions as the expression of sensitiveness to change in intensity of a stimulus (Unterschiedsempfindlichkeit), in order to distinguish them from tropisms.[17]

It is hardly necessary to point out here that the effects of rapid changes in intensity, when they are very marked, can easily complicate and entirely obscure the heliotropic phenomena. In *Hypotricha* and other infusoria this sense of difference is very pronounced in response to sudden touch or sudden alteration of the chemical medium, and like

[17] Loeb, "Uber die Umwandlung positiv heliotropischer Tiere usw," *Pflügers Archiv,* 1893. See also the recent investigations of Georg Bohn, "La naissance de l'intelligence," Paris, 1909; "Les essais et les erreurs chez les étioles de mer," *Bull. Inst. gén. psychol.,* 1907; "Intervention des réactions oscillatoires dans les tropismes," *Ass. franc. d. Sciences,* 1907.

the tube-worms they thereupon draw back very quickly. Since their locomotor organs are not symmetrical, but are arranged in a peculiar unsymmetrical manner, they do not, after the next progressive movement return to the former direction of movement, but deviate sideways from it, and it is, therefore, easy to understand that such animals do not furnish the best material to demonstrate the laws of heliotropism, especially since they possess, moreover, only a slight photochemical sensitiveness. But Jennings has with special preference used observations on such organisms to argue against the theory of tropisms, and he has with these arguments caused much confusion in the minds of zoologists. One writer has, if I am not mistaken, asserted that the significance of tropisms is limited by the demonstration of the sense of difference. This writer overlooks the fact that it is a question of tracing psychical phenomena, and not merely tropisms, back to physico-chemical processes. Just as in muscles and nerves the action of a constant current is different from that of an intermittent current, so we find in the action of light an analogous case. If we wish to trace all animal reactions back to physico-chemical laws we must take into consideration besides the tropisms not only the facts of the sense of difference, but also all other facts which exert an influence upon the reactions. The influence of that mechanism which we call "associative memory" also belongs in this category, but we can not discuss that further here. Instead the reader is referred to my aforementioned book, as well as the newer work of Bohn, "La naissance de l'intelligence."[18] Let us bear in mind that "ideas" also can act, much as acids do for the heliotropism of certain animals, namely, to increase the sensitiveness to certain stimuli, and thus can lead to tropism-like movements or actions directed toward a goal.[19]

IX

Besides light and the electric current, the force of gravity also has an orienting influence upon a number of animals. The majority of such animals are forced to turn their heads away from the center of the earth and to creep upward. It was uncertain for a long time how the orientation of cells in relation to the center of gravity of the earth could influence the rate of the chemical reactions within, but it has been suggested that an enlargement or shifting of the reacting surfaces formed the essential connecting link. If it is assumed that in such geotropically sensitive cells two phases (for instance, two fluid substances which are not at all, or not easily, miscible, or one solid and one fluid substance) of different specific gravities are present, which react upon one another a reaction takes place at the surfaces of contact. Every

[18] "Comparative Physiology of the Brain and Comparative Psychology," New York and London, 1900.

[19] Paris, "Bibliothèque de Philosophie scientifique," 1909.

enlargement of the latter increases the mass of reacting molecules. A shifting of the contact surfaces would act in the same manner. Finally, a third possibility remains which could perhaps be realized in plant roots and stems. If in the geotropically sensitive elements two masses of different specific gravity are present, only one of which reacts to the flowing sap in the center or the periphery of the stem, the cells of the upper side of a stem which is laid horizontally will acquire a different rate of reaction from those of the lower side, because in the former the specifically heavier substances are directed toward the center of the stem, while in the latter the specifically lighter ones are directed toward the center. Consequently, one side will grow faster than the other, and thence the geotropic bending.[20] In the frog's egg, we can actually directly demonstrate the existence of two substances of different specific gravity and can study their behavior, since in this case they are of different color.

In animals it has been observed that orientation toward the center of gravity of the earth often becomes less compulsory when the inner ear has been removed. Mach first pointed out the possibility that the otoliths are responsible for this. They might press upon the end-organs of the sensory nerves and every change of pressure might cause a correction of the position of the animal. It is generally assumed that this view has been verified by experiment. I cannot, however, agree with this, although I once described experiments which seemed to support Mach's otolith theory. I had found that when the otoliths of the inner ear of the shark are scraped out with a sharp spoon the normal orientation of the animal suffers; but if the otoliths are simply washed out from the internal ear by a mild current of seawater the orientation of the animal does not suffer so easily.

In the latter case, the doubt is present as to whether all the otolith powder has been removed from the ear. The matter was decided by experiments on flounders, which have only a single large otolith which can easily be removed from the ear. E. P. Lyon carried out these experiments, which showed that no disturbance of the orientation resulted from this operation. We may conclude, therefore, that in my experiments of scraping out the otoliths a disturbance of the orientation occurred because by this means the nerve endings in the ears were injured. We have, therefore, no right to say that the orientation of animals in relation to the center of gravity of the earth is regulated by the pressure of the otoliths upon the nerve endings, but that this regulation takes place in the nerve endings themselves, and probably, indeed, as a result of the existence there of two different phases of different specific gravity which react upon one another. Through the change of

[20] Chapter Tropismen in "Vorlesungen über die Dynamik der Lebenserscheinungen."

orientation of the cells in relation to the center of gravity of the earth, the two phases undergo a shifting by means of which a change in the rate of reaction is brought about according to one of the ways given above. Since then I have looked through the literature on the function of the otoliths or statoliths, and have reached the conclusion that all writers who assert that the removal of the otoliths disturbs the geotropic orientation of animals have been victims of the same fallacy as myself. They have injured or removed the nerve endings. In the only case in which a removal of the otoliths without tearing or other injury of the nerve endings can be justifiably assumed, no disturbance of the orientation occurred.

While in my own work I have aimed to trace the complex reactions of animals to simpler reactions like those of plants and finally to physico-chemical laws, the opposite tendency has lately been gaining influence. Some botanists, namely, Haberlandt, Němec and F. Darwin, endeavor to show that the relatively simpler reactions of plants may be traced back to the more complex relations found in animals. Instead of deriving the tropic reactions of plants as directly as possible from the law of mass action (and other physico-chemical laws), they try to show that "sense organs" exist in the cells of plants and Francé even attributes to the latter a "soul" and an "intelligence." I believe that in order to be consistent, these writers ought to base the law of mass action upon the assumption of the existence of sense-organs, souls and intelligence in the molecules and ions. It is probably unnecessary to emphasize the fact that it is better for the progress of science to derive the more complex phenomena from simpler components than to do the contrary, namely, to try to explain the simpler by means of the more complex. For all "explanation" consists solely in the presentation of a phenomenon as an unequivocal function of the variables by which it is determined, and if in nature we find a function of two variables, it does not, in my opinion, tend toward progress to assert that this is a case of functions of more than two variables, without furnishing sufficient proof of this assertion.

These writers represent the geotropic reactions of plants by saying that in certain cells starch grains are present which serve the purpose of the otoliths in animals. These starch grains are believed to press upon the sense organs or nerve endings in the plant cells concerned and the pressure sense of the plant is then supposed to give rise to the geotropic curvature. I have no opposition to offer to the assumption that the starch grains change their position with a change in the position of the cells, and I am also willing to pass over for the present the view that the starch grains form one of the two phases in the cell. But I see no necessity for assuming besides this the existence of intracellular sense organs which perceive the pressure of the starch grains.

This is, in my opinion, an unnecessary complication of simple relations which in this case introduces a demonstrable error of animal physiology into plant physiology.

X

The progress of natural science depends upon the discovery of rationalistic elements or simple natural laws. We find that there are two classes of investigators in biology, grouped according to their attitude toward such simple laws or rationalistic elements. One seems to aim at the denial of the existence of such simple laws and every new case which does not fall at once under this law is an opportunity for them to point out the inadequacy of the latter. The other group of investigators aims to discover and not to disprove laws. When such investigators have discovered a simple law which is generally applicable, they know that an apparent exception does not necessarily overthrow the law, but that possibly an opportunity is offered for a new discovery and an extension of the old law. Mendel's laws have been brilliantly confirmed in a number of cases. In some cases of deviations (from these laws), however, it has not always been possible to recognize at once the causes of the same. One group of investigators has recognized that these deviations do not indicate the incorrectness of Mendel's laws, but that they are merely the result of secondary and often minor complications; the latter investigators have from this standpoint made further fruitful discoveries. The rôle of the other group of investigators in this case has consisted, primarily, in an attempt to minimize the importance of Mendel's laws and thus to retard the progress of science.

The case is similar in the realm of tropisms. Tropisms and tropism-like reactions are elements which make possible for us a rationalistic conception of the psychological reactions of animals on the basis of chemical mass action, and I believe, therefore, that it is in the interest of the progress of science to develop further the theory of animal tropisms. The fact that in an electric current the same animal often moves differently from what it does under the influence of light finds its explanation for the observer conversant with physical chemistry in the fact that the electric current causes changes in the concentration of ions within, as well as upon the surface, while the chemical action of light is essentially limited to the surface. Certain writers, however, leave this difference in the action of the two agents out of consideration and make use of the difference in the behavior of certain organisms in response to light and to the electric current, to assert that it is not permissible to speak of tropisms as being governed by general laws; in other words, they say that tropisms are without significance. Animals in general are symmetrically built and the motor elements of the right and left sides of the body usually act symmetrically. Consequently the heliotropic orientation, for instance, comes about as we have already described. There are animals, however, which move sideways, for instance, certain crabs, such as the fiddler crab. Holmes has found that these crustaceans also go sideways toward the light. Jennings draws from this fact the following conclusions: "The symmetrical position is an incident of the reaction, not its essence."

In other words, he uses these observations of Holmes to indicate that the rôle ascribed to symmetry has no importance for the theory of tropisms. I am, however, inclined to draw another conclusion, namely, that in the fiddler crabs in the first place there is an entirely different connection between the retina and the locomotor muscles from that in other crustaceans and different animals, and that, secondly, there is a special peculiarity in regard to the function of the two retinas whereby they do not act like symmetrical surface elements. I believe that a new discovery may be made here.[21]

XI

These data may suffice to explain my point of view. To me it is a question of making the facts of psychology accessible to analysis by means of physical chemistry. In this way it is already possible to reduce a set of reactions, namely, the tropisms to simple rationalistic relations. Many animals, because their body structure is not only morphologically, but, also chemically, symmetrical, are obliged to orient their bodies in a certain way in relation to certain centers of force, as, for instance, the source of light, an electric current, the center of gravity of the earth or chemical substances. This orientation is automatically regulated according to the law of mass action. The application of the law of mass action to this set of reactions is thus made possible. I consider it unnecessary to give up the term "comparative psychology," but I am of the opinion that the contents of comparative psychology will under the influence of the above-mentioned endeavors be different from the contents of speculative psychology. But I believe also that the further development of this subject will fall more to the lot of biologists trained in physical chemistry than to the specialists in psychology or zoology, for it is in general hardly to be expected that zoologists and psychologists who lack a physico-chemical training will feel attracted to the subject of tropisms.

In closing let me add a few remarks concerning the possible application of the investigations of tropisms.

[21] From which I expect, furthermore, that they will only confirm still more the laws of heliotropism. This expectation is based upon analogous relations in the pleuronectids, which I can not, however, discuss further here. However, probably no one will maintain that the existence of the pleuronectids invalidates all laws in regard to the symmetrical body structure.

I believe that the investigation of the conditions which produce tropisms may be of importance for psychiatry. If we can call forth in an animal otherwise indifferent to light by means of an acid a heliotropism which drives it irresistibly into a flame; if the same thing can be brought about about by means of a secretion of the reproductive glands; then we have given, I believe, a group of facts, within which the analogies necessary for psychiatry can be experimentally called forth and investigated.

These experiments may also attain a similar value for ethics. The highest manifestation of ethics, namely, the condition that human beings could be willing to sacrifice their lives for an idea is comprehensible neither from the utilitarian standpoint nor from that of the categorical imperative. In this case also it might possibly be that under the influence of certain ideas chemical changes, for instance, internal secretions within the body, might be produced which increase the sensitiveness to certain stimuli to such an unusual degree that such people become slaves to certain stimuli just as the copepods become slaves to the light. To-day, since Pawlow and his pupils have succeeded in causing the secretion of saliva in the dog by means of optic and acoustic signals, it no longer seems to us so strange that what the philosopher terms an "idea" is a process which can cause chemical activity in the body.

FEELING IN THE INTERPRETATION OF NATURE

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HUMAN beings, in common with all others, are as fundamentally esthetic and emotional as they are cognitive and rational. This conclusion I believe to be warranted not only by the facts presented by adult man in civilized society, but also by those observable in very early, simple stages of life everywhere. We do not say that an amœba *knows* the sensation it has when it comes in contact with a food-particle; nor that a babe *knows* the sensation that gives rise to the sucking reflex when first its lips touch the nipple or a finger tip. Yet both amœba and babe convert, or elaborate, the raw fact of contact into a set of activities that meets the needs of its existence. Each makes its contacts serve its own larger ends as surely as does the adult man; and no knowledge is worth anything if it does not do that.

So we have to recognize that the esthetic, the merely responsive aspect of our natures, and the psychically elaborative, the recognitive aspect, send their roots down to the very deepest layer of organic constitution; that the two come side by side from a common matrix of organization. Neither can be proved to have arisen earlier than the other, nor can either be shown to be derived from the other. This fundamental parity between intellect and feeling has vast significance for human welfare. Every philosophic system, every educational theory, every religious interpretation of life, which fails to recognize it is sure to be by so much inadequate.

One phase of this inadequacy is subjectivism in its many forms. Whether as idealism, vouched for in our day by Oxford and Harvard, and dressed out in great learning and brilliant dialectic as the "Absolute Good"; or as occultism, vouched for by Mahatmas and the "Mother Church, Scientist," and somewhat scorned by the more scholarly, the same error runs throughout. The former ignore all of man except that part of him which makes syllogisms; the latter goes to the opposite extreme and stifles the legitimate demands of the intelligence for clear and rational thinking. Both fail to recognize that we know-and-feel, all in one breath, whenever we respond in an unsophisticated, natural manner to contacts with men and things.

One of the places in which the intellectualist form of subjectivism has got in its stultifying work most disastrously, is in the education of children. In spite of spasmodic efforts at reform, the factors of spontaneous interest and emotional attitude have been practically ignored. We have been trying to educate pieces of children.

We choose for discussion here one phase of the educational situation, education touching the living world. We choose this not because it is of transcendent value as compared with other aspects, but because the writer happens to be a biologist and a teacher.

Why is it that so few persons even among the educated are genuinely and broadly interested in and informed about plants and animals? Of course everybody cares for plants to the extent of wanting good table vegetables and fruits, and nearly everybody cares for flowers. Everybody, too, is interested in the domestic products of the animal world; and most of us have more or less fondness for a few pet animals. After this much has been said it will be allowed, I think, that nine tenths of all grown persons in Christian lands are quite indifferent to the myriads of plants and animals by which they are surrounded. Why is this? Perhaps some one asks what sense there is in such a question. To justify the contention that the great rank and file of mortals ought not to be thus indifferent, we must reflect a bit on the state of being alive, on its nature and scope.

Are you fond of living? Are you one of that great number of human beings who assent to the saying that life is the most interesting thing in the world, the thing to be most sought after, most watchfully tended? What life is it which you thus appraise? Human life, you say promptly; and that is well, so far. But what is human life? Is it something wholly apart from the living things round about you? Surely you have noted some elements in common between the human life you love so dearly and the lowly life you care so little for. And you have heard something of what the learned have made out about "Man's place in Nature."

I ask you to summon the best thought of which you are capable, and tell me if you have no feeling of selfishness, of smallness, of meanness, when you assert your love of life and mean by "life" nothing more than your own life and that of your family and friends, or even of humanity generally. On the other hand, tell me with equal candor, do you not have a sense of largeness, of generosity, of outgoing to all about you, when your love of life encompasses everything that lives?

By asking the question, Why are most persons so indifferent toward most living things, we approach the answer to the question: It is because our theory of life does not include all life, and because it is not made by our whole selves. It is made by the intellectual side of our natures; the affective, the emotional side having almost no part in the process.

I am sure that if the development of our race and our civilization goes on normally, man will reach after a time a synthesis of himself far more thoroughgoing than any yet attained; he will consolidate himself, will get together his powers and faculties, will reach a degree of integrity as yet only foreshadowed. When that time comes man will see as never before how much bigger a being he is than his intellect; how much more he can be and do by putting his whole self, his feeling, his emotion, his sentiment, as well as his mind and will, into his work.

In that day popular sentiment will not hold almost all creatures which are more or less obscure as utterly good-for-nothing and to be trodden underfoot without a passing thought; will not hold every worm, every spider, every snake forejudged and forecondemned as a poisonous "horrid thing." There will be a suspension of popular judgment in these matters, as there now is of scientific. There will be a general disposition to fair play toward all things that live; a desire to treat each according to its merits—to kill it, humanely, if it prove really harmful, or if undoubted benefit may come from so doing; but otherwise to allow it to go its way. And be it specially noted that the benefits of this new day will not end in better sentiment and feeling alone. Equally great good will come to knowledge and interpretation. A tinge of feeling, of sentiment, toward organisms promotes interest, interest promotes attention, and attention is an essential prerequisite to the acquisition of knowledge and to sound reasoning. We learn most quickly, most spontaneously, most comprehensively, most securely, things that interest us, and things interest us most toward which the affections go out.

It used to be said of Louis Agassiz that he handled his specimens as though he were in love with them; I submit the question to my fellow-students in zoology and botany: Do you not ordinarily come to have a real fondness for the animals and plants you study? I do, and do not hesitate to say that through this affectionate interest has come one of my main impulses to and satisfactions in zoology. I have no doubt that feeling has been an element in whatever of effectiveness my work has had. Of course the orthodox intellectualist's reply to this will be prompt and in its accustomed tone of finality. "Yes," most biologists will say, "we certainly are fond of the organisms we deal with. We have an eye for the gracefulness of form and movement and the beauty of color that abound everywhere among living things; but this has nothing to do with our biology." Some will go further and declare that not only does feeling contribute nothing to achievement in science, but that it is actually hostile to such achievement. To keep sentimentalism at arm's length is exactly one of the things biology has to do, they will say; and will point to the mischievousness of the modern nature-fakers.

This is not the place to consider either illegitimate or legitimate fancifulness in writing about animals. I merely express the conviction that much as is to be deplored the flood of mercenary falsity concerning nature that has been poured upon this generation, the whole thing has come about from a certain unappeased popular demand. There is a widespread and rapidly growing curiosity about and interest in animate beings. Such curiosity and interest lead inevitably to efforts for increased knowledge. The authoritative biology of the day has failed and is failing to meet this demand.

Let any teacher of botany or zoology in school or college, whose experience reaches back twenty years, consider the men and women of to-day who were once his pupils. Let him ask himself to what extent his efforts succeeded in making the plants and animals by which these men and women have since been constantly surrounded, vital, potent, perennial elements in the effectiveness of their lives. Testing your work thus, does the voice of conscience say well done? It surely does not for me, and I have no reason to suppose the instruction I gave during some fifteen years to general classes in the University of California was particularly worse than that given by most teachers. I made use of the regulation paraphernalia in the regulation way. There were the innumerable wall-charts carefully drawn and colored, with the proper conventions for ectoderm, mesoderm and entoderm, and for the various cell-parts during indirect cell-division, fertilization, and so forth. A fairly complete set of preparations to illustrate the lectures was at hand, some in bottles, some dry. The fundamental nature of living substance, "according to the latest and best authorities," and the fundamental difference between plants and animals, were early and concisely set forth. Near the beginning of the course the doctrine of evolution was made clear and impressive, and strong enough to sustain the weight of every fact that should later be brought forward.

The vast importance from the evolutionary standpoint of a few fundamental types, amœba, volvox, the calcareous sponges, the primitive annelid, *Amphioxus,* the shark, was duly insisted upon. The gastrula, the cœlome, the nephridia, the somites of the vertebrate head, and the rest of the thirty-nine articles of evolutionary faith were set forth. The "factors" of evolution were treated with generosity. Natural selection was of course given first place, but later mutation became its close second. Not only colored figures, but an actual specimen, naturally environed in a glass case, of *Kallima,* that wonderful leaf-butterfly which has been the cornerstone of a whole philosophy, was provided to illustrate protective resemblance; and various other instances of adaptation were shown. When the topic of animal psychology was reached, it was pointed out how easily and completely the tropism theory disposes of the vagary of earlier notions about the intelligence of lowly creatures, and the interesting point was made that in a simple caterpillar "reacting" up a stick we probably have in our hands the key to the whole mystery of mind in the living world.

Yet, in spite of this shining program, very, very few general students elected zoology and little glow of enthusiasm could be seen on the faces of those who did. Students in need of some biological knowledge for their later professional studies, and drifters from the non-scientific departments of the university in need of credits for graduation, were the chief constituency of the successive classes. Undoubtedly a few earnest men and women sought the course out of genuine desire for knowledge of the kind it was supposed to furnish. But how scattering these were I see as I look back in memory over the groups that came and went year by year.

And were my efforts of no avail at all? Did nothing whatever lodge permanently and potently in the minds of those students? I try to believe the case is not quite as bad as that, for the lectures and the laboratory work were given with much conscientious preparation and with real labor in the actual doing. Probably the *level of general intelligence* of the men and women who took the course is somewhat higher than it otherwise would have been. That is all, I much fear, that can be rightly claimed. None but we teachers whose professional reputations and personal interests are at stake will maintain for an instant that this is enough. Our teaching of botany and zoology has failed miserably, judged by what is due from it to the spiritual side of men's lives and to the higher reaches of civilization. Why? The central reason is clear: It is that certain fine-spun theories about "life," rather than animals and plants themselves, have been the main spring of our teaching. The metaphysics of biology and the microscope have stood as almost impenetrable screens between the perennially-interesting, everywhere-present, easily-seen facts of the living world, and the natural responsiveness of young learners.

We have not been metaphysicians by intent or even consciously. Indeed, a supposed fidelity to objective reality has made us loud in denunciation of metaphysics. Nevertheless, "fundamental questions," "ultimate problems," "complete explanations," "final solutions" and other phrases which abound in many biological discussions held as strictly up-to-date are but thin disguises, to discerning eyes, of genuine metaphysics. Far be it from me to pronounce general condemnation on metaphysics. Every domain of knowledge has, from the nature of things must have, its particular metaphysics. The indictment against metaphysics in this case is two-fold. First, metaphysics belongs by right only to advanced stages of learning in all fields, and so has no business whatever in formal instruction of the young. Second, the metaphysics that has dominated recent biology, while being bad in many ways, is especially sinister in its influence on education. Materialism, the theory now in widest favor, and vitalism, its chief rival, might be classed together so far as concerns some of their most essential aspects, under the designation *minutism,* the theory, that is, that the "final explanation" of all things is to be found only in the excessively small, mostly invisible parts or elements of those things. Hence the idolatrous attitude which much of biology has long held toward cells, nuclei, protoplasm, chromosomes, enzymes, biophores, determinants, etc., and hence the exclusion to so large an extent from real biological interest and endeavor, of organisms and parts of organisms which are large enough to be easily examined without the aid of the microscope.

The extent to which the zoology of our institutions of higher learning deals with invisible or difficultly visible animals; scraps of dead animals, and very small living animals either mutilated or placed in wholly unnatural surroundings, is remarkable once one comes to look at the situation broadly. The management of a zoological park or museum, in need of a trained zoologist as superintendent or curator; or the director of an agricultural station who should want an expert on the higher animal life of the region, might about as well appeal to a village kindergarten or a corner grocery for men equipped for such positions as to the department of zoology of most of the great universities of the country.

Persons who devote themselves to the study of living animals and plants, especially rather large, common ones like mammals and birds, and trees and grasses, and those who study the larger structural features of these larger organisms, can not, according to the prevalent view, be admitted to the small, inner-chambered class of philosophical biologists, but must remain outside with the great commonality as mere "mammal men" and "bird men," or, with some condescension, as "mammalogists" and "ornithologists," and as mere "systematic botanists."

We have made the sorry blunder of reasoning that since it has been found impossible to make knowledge of organisms thoroughgoing at any point without becoming microscopists and chemists, therefore, by becoming these exclusively, after awhile we shall have plumbed the deepest depths of the living world.

The only justification for speaking of these family dissensions within the biological household is that this much seemed necessary as preliminary to the expression of my conviction that should speculative biology ever become as strongly dominated by a carefully thought-out, wholesome metaphysics as it is now dominated by a meagerly informed, badly reasoned, unwholesome metaphysics, human beings and the higher animals and plants, taken living and whole, would be seen to be more interesting than simpler organisms and parts of organisms, just in proportion as the higher exceed the lower in complexity.

This reassessment of the living world as to degrees of interest would follow such a reformation in the metaphysics of biology since it would be seen that higher and the highest organisms are just as "ultimate," just as "fundamental," as are the lower and lowest organisms, and that the whole of any organism is as "ultimate" and "fundamental" as are any of its parts.

What this means said in every-day language is that a sorely defective general theory, or philosophy of living things, is preventing the recognized leaders in biological science from having any vital interest in the actual, living plants and animals with which common observation and intelligence come in contact.

So far my point has been that we can not interpret plant and animal life broadly and soundly either in technical science or in common intelligence unless the esthetic side of our nature joins with the intellectual side in determining our attitude toward the beings we deal with. Now I want to insist that the business of truly original study is always suffused and quickened by feeling. What investigator of nature who has ever made a real discovery, however small, does not know that an element of emotion was involved? True discovery is always, it seems, proportional to the imagination put into the effort that led to it; and imagination, even partially fulfilled in actual experience, is emotional through and through. The famous story that Newton was so agitated that he had to ask a friend to write for him when he saw his calculations concerning the attraction of the earth for the moon were finally going to be confirmed by Picard's lately corrected observations on the size of the earth might easily be true, whether it is or not.

Divorce science from feeling as completely as some men of science seem to believe it ought to be divorced, and science is dead formalism. Real progress in it is at an end. Highly specialized research untouched by imagination is worse than dead, it is a birth that has never been "quickened." In it you have "science for its own sake" sure enough, for it becomes so much a thing of technique, of strange new words, and of old words with twisted meanings, that none but the esoterics can make any sense out of it, much less any practical use. Normal warm-blooded human beings are not greatly attracted to a science

> Where soul is dead, and feeling hath no place;
> Where knowledge, ill begun in cold remark
> On outward things, with formal inference ends,
> Or, if the mind turn inward, 'tis perplexed,
> Lost in a gloom of uninspired research.

But a practical difficulty, the question of what is possible in one short lifetime, is sure to be raised here. Does this liberal attitude toward nature, this breadth of interest and knowledge, spell its own practical if not its theoretical defeat? Does it make demands upon investigation and upon instruction of the young which can not be met because of the limited capacities of mortal beings? Does it mean superficiality still more wide-spread and debilitating than it is now? Not at all. Paradoxical as it may seem, the very conditions that would produce a broader knowledge of living things would make that knowledge more accurate and penetrating.

Once see clearly how much more educational effort can accomplish with small children when it takes advantage of curiosity about, and spontaneous interest in, nature, than when it tries to compel interest, and one of the main ways of escape from the difficulty here indicated will have been found. As to more advanced youths and adults, the belief is altogether too widely and influentially held that interest in nature is more dependent upon continuous work with and exhaustive knowledge of the particular sections of nature concerned, than is actually the case. Under the guidance of a free and expansive general theory of living nature a keen and genuinely elevating interest in a vast range of things about which one's technical knowledge is rather meager, is undoubtedly possible.

The dread of superficiality entertained by professional biologists, while justifiable to a certain extent, is yet often strongly tinctured with the notion that profundity of knowledge means knowledge of the deeply located parts of organisms; and contrariwise, that any knowledge of the exterior, easily visible parts and activities is superficial. This tincturing is another of the results of the bad metaphysics already referred to.

But perhaps the most important consideration under this head concerns the powers of men. Human beings are indeed limited in capacity. No one can learn or do everything. Yet exactly where are the bounds of human capacity? What psychologist has determined accurately the utmost limits of the power of acquisition by any given human mind? When we ascribe limitations to the powers of the mind it is vitally important that we measure our words. There is a vast difference between recognizing that limits do exist and knowing just where they are.

Such expressions as "we can do anything we really want to do," and "we can do what we must do," though so long familiar in common life, are only now coming to scientific definiteness of meaning in psychology and biology. We must presently become aware that the discovery of the unused spiritual and physical capacities of the human being is of transcendent importance; and but for the circumstance that our dominant biological philosophy has had no use for, and hence no interest in, the facts, it would be surprising that so little notice has been taken of them.

Who that has had anything to do with children has not noticed the facility with which they learn certain things, which they take up all by themselves, and which it seems there is no reason why they should learn? Conspicuous illustrations before us everywhere in the United

States just now are the extent to which boys go into electricity, particularly wireless telegraphy; and the extent of their mastery over the automobile. Nothing has astonished me more than the quickness and thoroughness with which I have in several instances seen boys of from six to ten years learn the automobile when one has come into the family for the first time. I believe thousands of men throughout the land will bear witness from their own observations that an ordinary lad of ten will learn an automobile as readily and nearly as thoroughly as a full-fledged man, and with no seeming effort whatever.

How long, I ask any school teacher, do you suppose it would require for the same boy to master the automobile with equal thoroughness, were it to be taken into the school and studied in the usual school way with no other interests and notions than those ordinarily present in school learning? My own earlier experience as a teacher in the elementary schools, and my later observations on learning and acquiring skill, lead me to venture the opinion that no matter how long a boy should be taught the automobile by school methods under school conditions, he would never gain such a mastery over it as thousands of boys are now doing in a month or six weeks with no particular instruction at all. The principle is the same, I take it, as that of learning languages. We ordinarily make the sharpest distinction between native and foreign tongues. As a matter of fact, there is no such distinction to a child beginning to talk. To it one language is as native or as foreign as another and two or three, who knows how many? will be acquired simultaneously and with equal facility during the proper language-getting period and under the exigencies of real life.

The point for education is that in our systems as they are, the natural correlations between the stages of individual development and subjects to be acquired, native curiosity and interest, spontaneous spiritual and physical activity, and social and other environmental impingements upon the growing boy and girl, are given the most haphazard attention by those who make and operate the systems. In the matter of the child's contacts with and attitude toward natural history, I merely point out how objectively and largely a child's first knowledge is biological. Its contacts with its mother and its nurse, through all the avenues to its inner life, are continuous and vital. The first hours and days and months of a babe's life are a continuous laboratory course in biology. Then come the earliest wider contacts and noticings and curiosities and attentions and movings about. Think of the inevitable conquest of the family cat and dog, and the cow, the horse, the pig, the sheep, if by good fortune the youngster's world contains these animals. The nursery and the toy-shop, not the schoolroom and the educational supply store, tell the story of how the natural education of children runs.

Only a few days ago, in a discussion of the perennially debated, but never settled, nature-study question, a gentleman affirmed with considerable warmth that as to subject-matter the teacher must teach what "is interesting to her." There we have in a nut-shell one of the chief factors in the sore inadequacy of nearly all our efforts at formal instruction. The supposed needs of the future men and women rather than the present capacities, curiosities and activities of the children determine both subject and method. What is interesting, not to the child, but to the teacher, is the thing to be taught from the vast stores of physical nature.

Unfortunately even this topsy-turvy theory does not get much chance to show itself at its best, for too often what the teacher is really interested in is her pay. Thanks to the alertness and omnivorous curiosity of most children, things would go better if each teacher could handle subjects that do genuinely interest her. As a matter of fact, it is often true that the topics taught are not those which thoroughly interest any one in particular; they are rather those which, it is held, ought to interest everybody. The course of study, like the famous Mr. Herbert Spencer, "goes fishing with a generalization" for the interest of the "average child," which has not yet been shown to exist in the flesh. No wonder the actual Jacks and Jills fail to rise to the highly rational and theoretically attractive bait.

I have recently examined a large number of elementary text-books in zoology and botany, and several general works on the theory and practise of teaching, and have been much interested to find how unmistakably and almost invariably they reflect biological and psychological doctrines which are thoroughly antiquated. The word "antiquated" I use with deliberation. Basal conceptions have to be overhauled now and then; that is the way civilization gets ahead.

It is obvious to me that Dr. Boris Sidis is on the right road doctrinally, and the example he has given us in educating his own son is most important. Looking at young Sidis through the eyes of a biologist, I see not necessarily a "mutant," or "sport," but the result of a carefully worked out demonstration in nurture. It is an experiment I am able to verify at any time by giving the feral, stunted plants of our dry mesa lands about San Diego a better chance through stirring the soil around them, or summer watering.

There is no doubt in my mind that under a thoroughly natural educational procedure carried on partly in the home and partly in the school, any boy or girl capable of being well educated might be better educated at seventeen than any but very exceptional students are now when they are invested as bachelors by our best universities. By "better educated" I mean more broadly educated, more accurately, and, above all, more sympathetically and growingly educated. One of the most unfortunate things, it seems to me, about the education young people now get is the supposed *completedness* of it when the class-room door has been passed for the last time.

Any normal man or woman who looks back over his childhood finds at least a few great enthusiasms entering in the makeup of his early world, which came upon him unawares and were only dimly connected with the little exact knowledge he may have possessed. Some of the brightest memories of childhood are of feelings, vague, perhaps, but none the less real, as to the beauty, the vastness, the mystery of the world. The time

> Of splendour in the grass, of glory in the flower,

is no fiction for most persons. Poets' fancies are apt to find response somewhere in the constitution of most of us, however successfully we may have Bessemerized ourselves by mental discipline or business. Nearly all children, like nearly all primitive peoples, have in their natures the material out of which mystics are made; and of all the flames in human nature none burn higher and holier than that of mysticism. To utilize this raw material, not to the making of mystics but of sane, wholesome men and women, I conceive to be one of the great educational problems on the hands of this generation.

Education is failing so signally to meet the needs of rapidly advancing civilization because it is not calling forth the best powers of the boys and girls. It is not getting at these powers because it is not appealing to the real interests of the children; and it is not appealing to these interests because it is not taking the children whole; it is trying to educate pieces of children. Under an educational régime that should do no violence either to the nature of children or the nature of nature, I am convinced that much of the alert curiosity, lively imagination, automatic attention, and spontaneous acquisition characteristic of early childhood could and would be carried up into the later inevitable strenuosity and anxiety of advanced scholarship and "sure-enough" life.

Emerson somewhere exclaims, "The earlier generations saw God face to face; we through their eyes. Why should not we also enjoy an original relation to nature?"

The kernel of the educational problem, at least as regards nature, is here. Not only "earlier generations" but our own children, enjoy "an original relation to nature." That they ever lose that relation, is largely chargeable to defective education.

THE TYPHOID FLY ON THE MINNESOTA IRON RANGE[1]

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TOWARD the northern part of Minnesota, running from a point near Coleraine and Hibbing on the west to Ely on the east, is a low ridge of land, on an average about 1,200 feet above seal level, known, as most of you are aware, as the Minnesota Iron Range. It is not out of place to say that the industries associated with iron mining on this range give employment to over 200,000 people, all told, and of this number about 16,000, represented by Finns, Austrians (in the broadest sense of that term), Italians and a few Swedes, labor day and night to bring to the surface and send to Duluth, in carloads, the iron ore which enriches the coffers of the United States Steel Company. These latter are the miners, the actual workers with pick and shovel, and it is of these and their environment, and their relations to the common house fly of which we wish to speak.

I used the expression "bring to the surface." Let me hasten to say that a very large proportion of this mining is surface mining, and the mines are, for the most part, particularly in the Hibbing district, huge open valleys, made by stripping the surface covering the ore for a depth varying from fourteen to one hundred and fifty feet. Below this stripping there may be anywhere from fifty to two hundred feet of ore, and the removal of this, and the strippings, leaves enormous holes, resembling huge craters of extinct volcanoes. So deep are some of these artificial canyons, and so tremendous the mountainous piles of gravel and sand which constitute the strippings, that the entire topography of that part of the country is being strikingly changed, and one would imagine the phenomenon there observed to be the result of a mighty convulsion, or of several convulsions of the earth's crust, did he not see, far below him, as he stands on the edge of one of these mines, countless men at work, and busy engines, steam shovels and trains of ore cars running on temporary tracks, either carrying off the strippings, or bringing up the precious ore, which is soon speeding on its way to Duluth.

I have emphasized the fact of the existence of open mines in order to make it clear that these men are working in the open air, and under conditions which should be, other things being equal, in the highest

[1] Address, illustrated by lantern slide and moving pictures, delivered under the auspices of the Entomological Society of America, at their winter meeting in Minneapolis, December 28, 1910.

Dairy Barn—16 cows. Dung heap was removed the day before, leaving the entrance in the condition shown. An out-house is shown at the rear.

degree hygienic. The miners live in various localities; some in cheap boarding houses in the towns in the neighborhood of the mines, some in settlements or "locations," as they are called, smaller aggregations of dwellings, small villages, as it were, situated close to an open mine or shaft. Some live in camps—clusters of buildings of a much poorer sort than those alluded to above, more or less temporary in character and also located near the mines. Of these miners the Finns are by far the most cleanly and the most stable; almost all of the married miners are to be found in their ranks. The Austrians, by far outnumbering the other races, for the most part pass in and out of the country as chance dictates, and their domestic habits and the environment which they tolerate are so filthy as to lead one to suppose that they, above all others, would be the worst sufferers from typhoid. The Italians, more numerous than the Finns, less so than the Austrians, appear to vie with the latter in the matter of negligence of their surroundings. The Swedes, industrious and cleanly, are so few in number (less than 700 on the entire range in 1907) that we might practically disregard them in this discussion were it not for the fact that they suffered to some extent from typhoid in a recent epidemic, and for a reason to be explained later.

Now, in illustrating conditions which prevail in one portion of the

Iron Range, we are depicting conditions which are found practically over its entire length, and if the name of any town is mentioned, and pictures thrown on the screen illustrating unhygienic conditions in connection with any town or towns, it must be borne in mind that these are not the only towns, and the Iron Range not the only locality in Minnesota where conditions favorable for a typhoid epidemic exist.

The above-named aliens, who work with pick and shovel, are low in the social scale, most of them densely ignorant, the greater number of extremely unclean habits, fatalistic in their views, and more or less suspicious of well-meant overtures. The workmen in the employ of the stripping companies, firms who contract with the mining companies to remove the soil covering the ore, are composed of the same nationalities as those employed by the latter companies, and live in much the same conditions.

A manager of one of the stripping companies remarked, speaking of the Austrians, that they would not raise a hand to clean their houses or other surroundings; they will submit to having it done for them by the company, but soon revert to the more primitive and, to them, more pleasant state.

The Austrians, as the term is broadly used on the range, including the Hungarians and people coming from the small principalities in and

Same Barn as preceding Figure, showing the unsanitary condition of the entrance. The photographer endeavored to wade the manure holes and sunk to his knees in the water and manure.

about Austria and Hungary, are locally called "Hunyaks" and the Italians "Dagoes." A "white," in range parlance, is a Swede or any one of the higher class of laborers who works steadily at his job. The employees in the offices of the mining companies, as well as the citizens generally, fall under the latter appellation. It is doubtful if the European homes of these people, almost the only people evidently who are attracted, at present, to this class of work, are as filthy as the conditions with which they are surrounded here, conditions which are a menace to the health of any community.

Creek where Sewage Empties.

We find, on the range, houses, boarding houses and others, swarming with flies. We find garbage cans, old, dirty stables sheltering miserable cows and horses, with the accompanying manure pile, and the dangerous open privy close to dwellings; dish water and other filth deposited in close proximity to wells, dairies that are unholy, so horrible are the conditions of their environment; sidewalks covered with the expectorations of all sorts and conditions of men, through which and over which filth walk hordes of flies in summer and early fall; alleys there are, too, the filth in which can hardly be described. Last, but by no means least, we note absence of screens in the windows and doors of dwelling houses, or, if there are any screens at all in a house, the good they might do is nullified by the presence of other screenless windows or screenless doors in the same building. Add to these conditions dense ignorance on matters of hygiene, indifference and intolerance of being interfered with, together with the fatalistic spirit above referred to, and one realizes that conditions there are almost always ripe for an epidemic.

It is hardly necessary to dwell at length on the house fly, now known as the typhoid fly, as a factor in the spread of the disease from which it is named. The excellent work of Dr. Howard along these lines, as well as later investigations, has placed the responsibility of one means of dissemination of typhoid where it belongs, and, as you well know, although we should still have typhoid if the house fly did not exist, and in spite of the fact that other insects may well carry the germ, the house fly is so evidently the chief offender that the name, "typhoid fly," is a very proper one to call attention to the danger of its presence.

In the eighties the possibility of flies carrying disease germs was called to the attention of physicians and the public. In 1898 we find what is perhaps the first reference to observations on the house fly's frequenting typhoid excreta, and thence flying to food, and the statement that bacterial cultures were obtained from both fly tracks and fly specks. Closely following this, in 1899, came the outbreak of typhoid amongst our soldiers in camp at Porto Principe, and Major Reed's report to the War Department that the epidemic was due to flies. The public then began to turn its serious attention toward the fly question. In 1900 Howard's article, published in the *Proceedings of the Washington Academy of Sciences*, on "A Contribution to the Study of the Insect Fauna of Human Excrement," further emphasized the great danger from the presence of flies in the household, and, as the house fly is the most common fly in that locality, designated that insect especially as an enemy to health. Work of different observers along these lines followed rapidly enough, every year showing additions to the evidence against this common insect, and the campaign against it was inaugurated, but it was not until recently that, as significant of its habits, and in order to help in this battle, the name of "typhoid fly" was suggested and adopted by entomologists.

We know that it may carry typhoid germs on its feet, on the hairs over its body, and in its alimentary canal and that these germs may live and be potent for some time even after having passed through its intestine. We know, in view of recent work, that this fly not only breeds in horse manure, but also in human excrement and other forms of filth, and it is a matter of common observation that this insect frequents all kinds of pollution from which it may carry disease germs to human food. You will readily see then, from the description of the domestic conditions prevailing amongst the miners on the Iron Range,

Milk House, showing the close proximity of a privy which was open to flies. The privy is the shed just behind the horse. The horse is standing in the drain from milk house, which was being used as a wallowing place for pigs.

a description not at all exaggerated, that the opportunities for a siege of typhoid during the months that this fly is abundant with us are most excellent. These conditions were found on the occasion of a visit to the range in the early part of last September, the trip being taken at the invitation of a member of the state board of health, who was anxious to have it made clear just how far the house fly was responsible for the epidemic.

We were told that the flies were more abundant than usual this year, the accuracy of which statement is open to doubt, for it is possible that observations in two successive seasons were made at different dates, flies naturally being more abundant in early September than in July. We believe, too, that the prevailing dryness this year may have caused the flies to congregate in larger numbers in the mining settlements where they found an abundance of moisture and filth as well. In this connection it may be said that, in riding over the range in an automobile at that time of the year, it was perfectly possible to realize that we were approaching a settlement, some time before it came in view by the odor wafted to our nostrils. Now, flies are gifted with a keen sense of smell, and it is a perfectly natural supposition that they are attracted from quite a distance, just as we were repelled, and that gathering in these somewhat circumscribed settlements or "locations," they gave the impression that they were more numerous this year than last. In the sense that their numbers were more concentrated, owing to the limitation of moisture—a prime necessity in the life of a fly—this is probably true.

It may be of interest to consider some statistics, showing to what enormous numbers the descendants of one fly may reach in the course of a summer. As most of you are aware, the eggs of a house fly hatch in from approximately six to twelve hours, and the maggots issuing therefrom reach their full size in from four to seven days. The outer layers of their body then harden and turn brown, forming the puparium, while the parts within become what is known as the pupa. The duration of the pupal stage is from five to seven days, at the expiration of which time the adult emerges as a perfect fly. The life of the house fly then occupies from ten to twelve days, and there may be from ten to thirteen or more generations in a summer, depending upon the character of the season and on the latitude. Of the length of life of the adult we can not speak with certainty, for the only way this could be determined is by confining the insects, and when this is done, conditions of existence are so unnatural that observations upon this point are not reliable. A female house fly which has hibernated

THE UNSANITARY CONDITION OF THE REAR END OF A RESTAURANT OFF FROM AN ALLEY.

in a dwelling house, or elsewhere, may produce in the spring, at the lowest estimate, one hundred and twenty eggs. Assuming that one half of these hatch as females, and allowing that the breeding goes on without check for four months, we have as the descendants of a single hibernating individual 214,557,-844,320,000,000,000,000 flies. Now, a house fly measures exactly one fourth of an inch in length; the distance around the earth at the equator is said to be 24,800 miles. It would take, therefore 3,688,312,-000 flies placed end to end to go around the world once. Using this number as a denominator, and the number of flies produced in four months from one mother as a numerator, we find she will give rise, in the course of a summer, to enough flies to encircle the globe at the equator five thousand times, and have plenty of progeny to spare!

An Alley near the Main Street of the Town.

In considering the relation of the house fly to typhoid, the question as to how far a fly can travel may suggest itself as an important factor, as, indeed, it is. We can not speak definitely as to how far a house fly can go by its own unaided effort. It is evident, however, that by making a series of flights this insect could cover a considerable distance. It does not, however, have to depend upon its own powers for getting from place to place; railroad and street cars, carriages and automobiles, provision wagons, meat carts, horses, cows and other animals all do their part in carrying this pest free of charge.

Virginia, Min.

In an out-house in the background the excreta from a typhoid patient were deposited. The water in this pond was used at that time by some of the neighbors for washing.

Turning once more to the consideration of conditions on the Iron Range we should naturally expect to have found typhoid most rampant among the most filthy of the three nations represented, but, strangely enough, such was not the case, for the Finns, the most cleanly of all, were the chief sufferers, not the Italians nor the Austrians. It is regarded as highly probable that this is due to the fact that the Finns lunch frequently during the day on cold food constantly exposed on their tables, while the Italians have three hot meals, and the Austrians also eat hot, recently cooked food. The Austrians and the Italians, I am told, use but little milk, and the Italians are great beer drinkers. The Swedes, like the Finns, have the same habit of eating cold food, and they, too, suffered from typhoid.

Is it any wonder, in view of the proximity of fever, filth and food, which I have tried to describe as existing there, and which the pictures shortly to be shown on the screen will still further illustrate, that the difficulties presented to the state board of health in combating the disease are very hard to overcome. I beg leave, however, to again remind you that the conditions which are pictured are such as might occur in any mining district where education did not have a constantly controlling influence.

I have already spoken of the foul smells emanating from some of the camps, and also from some of the locations. We found that in one or two of the camps where there was a breeze there were fewer flies than in others not so situated. But it should be borne in mind that a very few flies, if conditions are right, may be the cause of several cases of typhoid in a locality, and, conversely, the presence of hordes of flies would not necessarily mean typhoid when other conditions were unfavorable for this disease. We visited two or three or more miners' boarding houses where there were either cases of typhoid at the time of our visit, or from which typhoid patients had but recently been removed. The landlady in practically each case not only took care of the patient until he could be given a bed at the hospital, if indeed he were fortunate enough to secure entrance there, but also cooked for her boarders. Almost invariably in every such case we found the open privy, and windows more or less innocent of screens. At one such place visited, the conscientious housewife pointed proudly to her table, which was, with its burden of cold food, covered with netting, as she hastened to explain, to show her intelligence in this particular, "Oh yes, we always screen our table here." But here, and in many other similar situations, the flies were under the netting, crawling in large numbers over crackers, cakes and other so-called eatables, which many of these people keep on their tables all the time. At a house which contained a typhoid sufferer, the privy which received the refuse from the sick room was on the bank of a lake or pond, and this pond furnished water for washing to at least one family in the immediate vicinity. At one location visited there had been a case of typhoid in a house adjoining a dairy where about twelve cows were kept. The doctors accompanying us were known to the people, and one was asked to look

Austrian Bedroom.

at the dairyman's wife, who was "ailing." He diagnosed the case immediately as incipient typhoid, and the milk man, whose milk house, by the way, was quite a fly trap, was told that he must take his wife immediately to a hospital at Hibbing or elsewhere, or stop doing business. He chose the former alternative. This case is mentioned as showing the need of constant, intelligent supervision of these people on the part of conscientous experts. Why more of them do not die of typhoid, under existing conditions, is a wonder! The same kindly providence which keeps an intoxicated man from harm must be caring for them in their blind ignorance!

The epidemic of typhoid last summer, at Hibbing, at least, did not originate in the water. Nor could we trace the disease along any milk route, in spite of the filthy conditions in connection with dairies. It is interesting to conjecture at this point just how dangerous it is to eat dry food contaminated with typhoid germs from a fly's body. Moist food, of course, so impregnated, would, in the majority of cases, be far more dangerous, and of all the moist foods, milk is perhaps one of the best culture fluids for these germs. It is not improbable, then, that although, by some lucky accident, typhoid did not originate in the dairies themselves, and the milk was brought to the consumer in a fairly good condition, it was there, in the house, in many cases, inoculated by filthy flies, and the numbers of the deadly bacilli tremendously increased.

Among other circumstances favorable for an epidemic at Hibbing, we must not forget to mention the fact that the city sewer, receiving the refuse from this town of about 12,000 or more people, empties into an open creek not more than half a mile from the city. This creek is crossed by two or more bridges, over which delivery wagons pass many times a day to outlying towns. We stopped our carriage at one of these bridges, and watched the slowly moving filth for a short time, noting, upon driving to town, that we brought from that locality many flies upon the vehicle we occupied. Multiply this incident by a hundred and you have an idea of the many daily opportunities presented to flies for reaching the various towns in the vicinity.

This siege of typhoid had been preceded by one of dysentery earlier in the season, but this first appearance of dysentery was directly traceable to the water, for at that time the sterilizing plant had not been installed, and men had been working for some time in the shaft from which Hibbing got its water supply. I was told by a local physician that they could predict, in that town, an epidemic of typhoid after one of dysentery—dysentery appearing to make the system especially susceptible to the former disease. In this town alone, about the middle of May, there were nearly or quite 2,000 cases of dysentery, which ceased at once upon the purification of the water; and there was considerable dysentery present at the time of our vist, without question due to fly infection. It differed from the water-caused dysentery in

A Miners' Boarding House in Town. In the summer time mosquito netting is thrown over the table, confining large numbers of flies which crawl over the exposed food.

symptoms and results, being mild, the patient having but little pain and nausea, and scarcely any fever, and further, in the latter mentioned cases, the patients lost no time from their work.

We made the statement that this latter epidemic of dysentery was due to fly infection. I think we speak advisedly upon this point, and can perhaps convince you that the spread of dysentery can be laid at

Austrians.

the door of the house fly in addition to other serious charges. Dysentery is rather a broad term, covering a number of very closely allied intestinal disorders, all presenting, however, the same general symptoms. We are told by physicians that there is no one specific germ of dysentery, and that it is apparently caused by an excess in the alimentary canal of a number of germs—*Bacillus coli* is one—found in manure and filth, germs normally existing in comparatively small numbers in a healthy individual. Now, about two years ago, almost all the inmates of a certain institution in Minnesota suddenly developed symptoms of intestinal disorder, which could be likened to dysentery. This was in the cold season, when no flies were present. The trouble was traced unmistakably to drinking water, which was contaminated by the stoppage of the sewer from the institution, causing sewage to back up and enter the well. These conditions, I am happy to say, have been rectified long since. We believe, therefore, that the dysentery in Hibbing in July and August of the present year was caused by germs of the same character, brought by the flies from garbage, manure and other filth to food or drinking water.

This closes our account of conditions existing in this district. Suffice it to say that we left that locality impressed with the existence of the following significant factors: Exposed foulness of all kinds, including pathological excreta, in close proximity to human food; an enormous number of flies congregating in towns and settlements, where an abundance of moisture and filth was found; absence of screens on windows and doors, and dense ignorance and indifference on the part of the miners.

In view of these conditions and the danger present every summer, the question as to what is going to be done about it is an important one. The difficulties which the state board of health and various city boards of health have to contend with have been set forth in the above. To what has been said we should also add that the foreigners, for the most part, have not been used to having medicine donated them in the old country, and refuse frequently to use the remedies offered by medical representatives. It is evidently a fact also that they are not used there to the civic freedom which they find in their new homes; that in the old country they were under closer and stricter surveillance, in other words, they were "kept in line with a club," metaphorically speaking. These factors, coupled with ignorance, indifference and a false attitude of resignation to every ill, are what the physicians of that section have to fight. Some of the miners will obtain and use the chloride of lime they are directed to apply to typhoid excreta emptied into open vaults; some will use it if it is brought to them, but many not only will not purchase it, but even if it is furnished them, have to be visited constantly and made to use it. This points to one crying need in this matter, namely, constant watchfulness over cases on the part of the city or state authorities. In addition, enforcement of municipal laws, increased hospital facilities on the part of the mining companies, additional sewers, pictorial warnings, or, in other words, illustrated circulars in the different languages, which they will read and heed. Preventive measures may have to be made compulsory. Each locality may have to furnish chloride of lime either at the expense of the city or mining companies, and daily official visits made by properly authorized officials to affected houses. The women of the higher classes, in defense of their own families, if for no more altruistic reason, may have to enter the crusade. They could do much among people who either can not or will not understand the dangers with which they are beset.

The cloud is not, however, without the traditional silver lining, and there is promise of better things.

The range is blessed with remarkably fine schools, in many instances housed in elegant and costly buildings, where the children of aliens appear to be eager to learn. In addition there are, in at least one town, night schools for those adults who have free evenings. These latter, I understand, are well patronized, and afford an opportunity, one would imagine, for some educational work along these lines. In Hibbing additional sewers are promised, construction to begin next spring, as well as stricter enforcement of the ordinances regarding the removal of manure piles, or the covering of the same.

In conclusion, let me repeat what was said in the early part of this lecture, that it is not intended by the above recital to stigmatize any town or towns whose names may have been mentioned this evening, for conditions very much as described may be found in many other places. Circumstances, however, are such on the Iron Range at present as to allow the typhoid fly to play a very important part in the lives of the miners.

WHAT MAKES A COLLEGE?

By Professor A. B. WOLFE

OBERLIN COLLEGE

FEW aspects of present educational thought are more striking than the persistent and telling criticism it is bringing to bear on the American College. The universal demand for efficiency in our national life has put the college on trial—and has caught it in a state of unpreparedness to make a consistent defense in its own behalf. Presidents and professors differ among themselves not only in holding widely diverse ideas on the difficult questions of college administration, but also with regard to the fundamental *purpose* of the college, but until this question is settled, and settled correctly, it is hopeless to look for well-founded and certain improvement in college efficiency. A wrong conception of the function of the college—an erroneous aim—may rob otherwise most ideal educational processes of their value and adaptation to our real needs.

The aim of the college must change with changing social needs. Failure to recognize this fact and to act upon it with sufficient decision and promptitude is precisely the reason why the American colleges have been caught napping. They have not kept pace with the needs of a nation undergoing an unprecedentedly rapid evolution.

A glance back at the motives and conditions which led to the establishment of most American colleges will make this clear. Most of the colleges—those not integral parts of great universities, at any rate —were established from religious motives by religious institutions. In the great middle west, where the greater portion of the colleges are situated, and where religious conviction and moral decency have been for decade after decade considered inseparable, the great bulk of the people have considered religious education an indispensable foundation for "character," and character as the be-all and end-all of education. "Character" has thus been announced everywhere and always the end of education, and the task of the college, "character-building." College faculties have gone to work at character as if it were an edifice to be built up brick by brick, stone by stone, very much in accordance with the flowery formulas so often, in the olden days, sounded forth from the college oratorical platforms. We now distrust the character and character-building formulæ a little. The terms have had too narrow a meaning, have too commonly lacked a rich and concretely significant content, to serve as really effective watchwords for the twentieth-century college. They have become, long since, catch phrases, to save us the need of reconstruction in educational thought. We need to set up as an end of education something just as fundamental as lies in the meat and kernel of these old shibboleths and at the same time more specifically and functionally related to modern social life and needs as they actually are. We need the classic virtues the moralists of all times have loved to dwell upon, but we need much more. We need the trained capacity, the knowledge and perspective, to turn these virtues to social account, to leaven them with a social consciousness, to render them effective by social insight. Goodness does not suffice. We demand efficiency. Meaning well is not enough. We know that hell is paved with good intentions, and that too often they are put to that uneconomical use through lack of knowledge of this poor earthly earth. We demand, therefore, significant knowledge—we will not tolerate the ignorance of prudery or the mere pride of erudition. Both these have been baneful influences in the college world. Ignorance we shall have to hold to be positively immoral, socially unproductive, and sometimes actually criminal. We are going to insist upon the productive life. We want moral *valuations* as well as economic valuations to be sound, and we are on the verge of discovering that we can not have one without the other. We want institutions, beliefs, social processes to stand on their own merit. Unswerving loyalty to authority no longer suffices. We demand rational, responsible, thought-out action.

But the small college, slow to catch the new spirit, or to sense the moral growth of the times, sticks to "character" as the ultima thule of education. Tucked away in some secluded and protected nook of geographical isolation, sequestered in pleasant preserves of philosophical individualism and theological conservatism, many a small college has felt, until comparatively recently, only the eddies of the great stream of social and intellectual unrest. While the world is painfully going through the throes of the birth of a new *Zeitgeist*, college faculties have been content, not uncommonly, to drone away on philosophies of forgotten epochs—afraid, apparently, to venture into the present lest it make dangerous demands upon old faiths—faiths educational and ecclesiastical, faiths economic and moral—faiths tried and true in great measure, and in their essence capable of meeting any critical test, but not as yet fully subjected to such a trying and purging fire as twentieth-century rationalism and scientific opportunism seem to some timid souls bound to prove. More than this, to pioneer an institution or a constituency into the undiscovered future means work, calls for exceptional foresight and circumspection, vigor of purpose, openness of mind, and strength to drag along those who, through fear or inertia, lag behind. To think along new lines, to cast overboard old habits of thought, to acquire new viewpoints, is a painful process; no mind likes to be remade; few have the power to keep themselves continuously in repair and in tune with the times. Yet these are the capacities essential to college presidents and to college teachers.

Another feature of the history of the small college explains its partial failure to respond promptly and effectively to the new needs of the time. Most colleges were originally not only religious but also denominational institutions, founded primarily to give "proper" education to men who were going into the ministry of the respective sects. In the early days sectarianism was assiduously inculcated, but as time wore on its outward trappings were discarded. The colleges, for all their shortcomings, had a mighty end in view. They believed in the moral life and they perceived that a liberal culture was a necessity for the leaders of that Christian morality they hoped, through church and school, to make universal. But their conceptions of morality, of the Christian life, and of culture were all often somewhat narrow, and nearly always lacked that element of adaptability to meet new social and moral issues which must now be counted an essential of true, constructive, productive, morality. It is not for us to blame them for this. We have rather to seek an explanation of the fact, and to point out how it crippled their efficiency and finally helped to bring them to the bar of critical judgment.

A certain narrowness of horizon cooperated with a deplorable lack of financial resources. Their limited horizon kept the colleges from seeing just how seriously lack of funds impaired efficiency, and conversely their limited resources narrowed their horizon. Both the theory and the practise of education were narrow because the colleges did not conceive an aim at the same time broadly fundamental and intimately and directly related to the specific needs of our national life. Moreover, they did not early enough begin vigorous efforts to get resources adequate to the demands of a broad culture. Their aim was intense often to the point of fanaticism, but it lacked breadth and adaptability to the actual facts of human nature and of social life. The restricted horizon of the colleges was, of course, to no small extent, due to the nature of the general moral and social environment of the society in which they were located. Like the society about them, and from which their students came, they proceeded on the assumption that morality is merely a matter of goodness. In spite of their "mental discipline" and "cultural studies" they came dangerously near to divorcing morality from intellect. In effect many colleges still take practically this position. They have not yet arrived at a social-efficiency or social-productivity theory of morality. Primarily the persistent, traditional view reflects the strict, non-adaptive tenets of old-time orthodoxy, in which the key note to the highest morality is surrender of the will and obedience to authority. Such a view glorified discipleship. It allowed reason and self-direction to go so far; then it demanded that loyalty to personal authority step in. Something of the inherent selfishness of medieval orthodoxy ate through our educational system. Rules were set up on every hand for student guidance—so many of them that we of these unregenerate days can only pause and marvel. Some hampering relics of these elaborate systems of legislation remain, and in a few women's colleges and coeducational institutions innumerable rules are still imposed upon the women, even where the men are practically without regulation, and where there is much talk of education as a training in the power of *self*-direction. The aim of it was and is moral discipline. It was discipline—no doubt of that—but whether it was training in self-direction is doubtful. We do not learn to swim by being kept away from the water. Trained in a negative morality, a morality of shibboleths, a morality of restraint, it is not strange that many of the graduates of these older days have to-day inadequate ideas of what American society must demand from its educated men and women.

Moral discipline was matched by mental discipline. Certain subjects were thought peculiarly adapted to mind training. Of course these were the classics, mathematics and philosophy. Then science, with difficulty, got a foothold in the curriculum, and eventually large sums were spent in the equipment of laboratories. For a long time, however, there was more or less scorn of material equipment, unless in the shape of ornate buildings useful not only for academic purposes, but for advertising as well. Even the physical sciences did not have a universally cordial welcome. For many years the biological sciences were viewed askance; and the modern sciences of society had to creep in surreptitiously and apologetically through the side door of philosophy. Mark Hopkins and his log were a sadly overworked simile. From the first, the weak point in the theory of collegiate education was the idea of compulsory morality, and the corollary notion that intellectuality along broad lines of advancing scholarship was in some ways a dangerous luxury. Not infrequently, even now, do we hear scornful mention of "mere scholarship"—and this not from cub undergraduates, but from seasoned professors who should know better. Intellectual capacity in a student is not infrequently thought a matter secondary to his belief in the virgin birth of Christ or the regularity with which he attends church. In the professor scholarship is too often deemed of less importance than his ability to "influence" students through personal contact. Many a thoughtful person, observing small college ideals from the inside, is coming to believe that they give too large a place to personal loyalty and personal influence and too little to rational scholarship. Here we are close to the great and vital shortcoming of the American small college. It has not duly recognized the moral value of intellect and scholarship; it has not furnished its professors with sufficient means or stimuli for scholarship on their own behalf, nor has it insisted upon anything but the veriest mediocrity of attainment on the part of its students. Not recognizing the value of high scholarship in social service, it has not looked after the character and effectiveness of its resources from the point of view of changing social needs.

No one will deny for a moment that the colleges have rendered indispensable service to the country in spite of their lack of resources and of their point of view with regard to scholarship—some indeed will say because of it. It is time, however, that every institution of higher learning should eschew the old notion of compulsory morality and of the paramount desirability of personal influence irrespective of rhyme or reason. Other things being equal, the man of the greatest intellectual equipment will be the most moral man because in the long run he will be most effective in advancing the social welfare. The chances are that he will have just as much desire to do good as his less well-equipped brother; and he will have in addition the very essential capacity of directing his forces to the good end he desires to accomplish. The small colleges have worked faithfully to make other things equal, but only in the universities and in the larger colleges is there yet much true insight into the social value of genuine scholarship, or sufficient recognition that morality and knowledge go hand in hand. If the universities have erred in one direction—letting "moral discipline" go by the board—the colleges have erred in the other. What the colleges have now more explicitly to recognize is that the world to-day needs men and women whose good intentions, whose Christian "character," are directed and made effective by *scientific knowledge of things as they are,* by hardheaded capacity and courage to think, by energy to act rationally and with sympathetic understanding, even in the face of complex difficulties and unkindly criticism; and that it is the business of the college to develop the potentialities of such capacity.

To develop these basic powers we must have the right processes, and, back of the process, sufficient resources, for without resources the education needful to-day is an impossibility. The educational resources of the college are its material equipment, its students, and its faculty—and the greatest of these is the faculty. When all is said, the faculty makes the college—and scholarship makes the faculty. But even now the colleges recognize this but vaguely, and with some reluctance, perhaps because the men the universities have supplied to them as teachers have had often a sort of non-human, pseudo-scholarship of useless erudition, rather than the real scholarship and the real enthusiasms of men and women who not only know their own subjects passably well, but are deeply enough interested in human life to wish their work to have some direct and tangible relation to it. Given a faculty with genuine scholarship of this kind, with a reasonable average of experience in teaching and acquaintance with educational theory, with a consciousness of the problems of the college in its relation to the educational needs of a democracy undergoing the strains of growth and transition and with the morality of the average educated man or woman, and you have the great, prime essential of a college. Without such a faculty, all the fine buildings, all the magnitude, all the alumni associations and other institutional paraphernalia in the world are dross and tinsel.

It is a popular saying in the colleges that the business of the college professor is to teach. Often this carries the implication that a man can be an ideal teacher and not be doing some original work in his own particular field. No educational fallacy ever did more mischief than this. Different ideals of work and purpose must no doubt govern the college professor and the university research professor, but in the long run it goes without saying that even the college professor will teach better if he has some time for what the universities call productive work. It is an error to suppose that a man can teach a subject without knowing it; and it seems self-evident that his knowledge will be more thorough and more effectively interesting to his students if he himself is trying, in however modest a way, to advance human knowledge within his subject. The man of fine, keen scholarship in his own line, who tries to see the relation of his subject to life as a whole, will develop in the long run not only the strongest intellectual capacity, but also the strongest and most desirably influential personality. Moreover, he will ordinarily be scrupulous in the use of his influence. A scathing criticism might be made of the practise of some college professors who seek by their own personal hold on a student to close his mind once for all to ideas contrary to those they themselves happen to entertain. The net result of such influence is too often an arrested development of the student's mind before it has had a fair chance to open.

Why now do the universities possess so many men of fine scholarship and the great personality that so often goes with it, while the colleges show comparatively so few? Some will deny the truth of this allegation, but no denial can really stand against the fact that the greatest teachers of the country are nearly always to be found in its universities. The colleges can not ordinarily hold their best men permanently and there are two valid reasons why they can not do so—lack of money, and lack of stimuli. It takes stimulating surroundings to develop a scholar. The university affords the stimulus to productive scholarship which the college lacks. The stimulus offered by the college is usually "the opportunity one has here to influence young men and women through personal character." Now it must be admitted that this is an effective appeal, very often, but how much more effective is it when it adds the opportunity of influence through solid, vital scholarship! The universities draft away the men the colleges need most—those who combine large scholarship with fine personality—because these men tire of the restricted horizon of life in a small college town, and because they perceive that they must have larger opportunities for growth and contact with the great world, if their usefulness is not in some degree to atrophy or ossify. College teachers are not, as a rule, clamoring for larger salaries because they love the dollar for its own sake, but because they recognize that financial resources are the bed rock of their own efficiency. Most of the captious criticism of the college by business men falls by the way because they expect a professor on a salary of $2,500 to yield a grade of service the business world considers itself lucky to get at $25,000. It is often said that the best men do not go into teaching because salaries are so low. This puts the cart before the horse. Not only would doubling the salaries paid by small colleges bring in a higher average of ability, but no reasonable doubt can exist that it would result in a marked increase in the efficiency of present instructors and professors. The most promising personal ability may yield disappointingly small results by reason of insufficient material support and absence of the proper incitement. If there is one fault preeminently true of the modern small college professor, east or west, it is lack of knowledge of the real world of to-day, lack of stimulating contact with men and leaders in other walks of life. The college teacher's time is spent largely in contact with immature personalities, very interesting generally, very stimulating sometimes, but nevertheless immature. This is perhaps one reason why whole faculties come momentarily to lack true perspective on moral and intellectual values. It is one reason, also, why we are sometimes slow to sense the nation's real educational needs and continue to insist upon antiquated disciplines and outworn curricula. It is the exceptional college teacher who has time to pause in his work and ask himself, "What am I here for?"

The faculty then makes the college and scholarship makes the faculty. This granted as substantially true, there is but one sure way of getting a scholarly faculty. Pay salaries large enough to call forth, to develop, and to retain ability. The average young doctor of philosophy can with propriety hardly be called an educated man, in a broad sense of the term. He lacks breadth of reading, travel, the stimulating and mellow fellowship of men in callings other than his own; he has not done a tremendous amount of thinking nor has he thought very deeply or broadly; he lacks, in short, the schooling of a rich and assimilated experience. The maturity, breadth of horizon and catholicity which should characterize the college professor, wherever found, are too often lacking. If the young doctor goes into a college, often removed from the real intellectual centers, from adequate libraries, from the main currents of contemporary thought and interest, he is in a fair way to remain for some time essentially immature, and then to undergo premature ossification. The small colleges of the past have sought primarily to recruit their faculties with men of "personality and character." If of late they have put somewhat more emphasis on scholarly attainments, still inability to pay good salaries has necessitated reliance upon graduate loyalty to the college in securing new instructors and professors. The result has been an undue proportion of their own alumni on faculties. Inbreeding in college faculties is as disastrous as it is elsewhere. The colleges are doomed to continued inefficiency unless salaries are increased a great deal more than most boards of trustees now have in mind. The college professor does not need to live in style, but he needs money just as much as many who do so live—he needs it for actual professional efficiency.

Not only does lack of funds hamper a college in securing a scholarly faculty; it means also more or less deficiency in the material equipment the faculty has to work with. Even Mark Hopkins had his log! Trustees, it is true, are too frequently dazzled by architects' plans and devote money to the erection of buildings which would better have gone to the building up of the faculty, but often, on the other hand, little attempt is made to furnish material equipment to teachers and departments so that they can do their work with a minimum drain of energy in routine and clerical work, and improve the actual effectiveness of their teaching. The science, language and mathematics departments usually fare the best, because they have established a vested interest in small classes and adequate (?) teaching force, and an elaborate material equipment of laboratory apparatus. The departments whose only laboratory is the library fare badly. It is comparatively easy to get donors to give for buildings but difficult to get money for salaries or books—which are the real library. A good library should be able to provide ample reading, reference and working material for all undergraduate demands, and in addition should spend a great deal of money upon journals and reviews, foreign works and reports of learned societies which never meet the undergraduate eye, but which nevertheless keep the teacher alive in his subject. How far most college libraries fall short of even the minimum requirement will be apparent to any one who looks up the statistics of American college libraries.

Lack of funds, then, hampers the development of that large, broad and human scholarship we need, not only because college poverty means low salaries, but because it means too few teachers, too wide a range of subjects for the same instructor to teach, too many hours a week of class-room work, too little time for original research and original thinking. "Out of hurry nothing noble ever did or can emerge," says a recent writer.[1] Hurried on one side by too much work to do, hampered, on the other, by a disastrous deficiency in library funds and material equipment, it is small wonder that the teaching of many a professor is sometimes mechanical and far removed from the actualities of life.

Here lies the great field for constructive administration. In so far as mentors of the college are planning devices for mechanically improving student scholarship through prizes and distinctions and the like, or

[1] C. H. Cooley, "Social Organization," p. 170.

are worrying about petty non-economies in routine administration, they are not getting down to essentials. They are rather distorting our perspective and confusing issues and values. We must *demand* more serious scholarship on the part of our students. And there is no surer way of getting it than to have more of it ourselves. We wish our students to develop true moral perspective. Again, there is no surer way for them to acquire it than to come into intellectual contact with men and women who have it. We get breadth of view only by widening the windows of the mind, not by crystal-gazing, however clear our crystal may be. The world needs to-day as much as ever it did a far-sighted, intelligent, self-directive morality. Never before, perhaps, have college faculties so needed capacity intelligently to weigh values, economic, political, social, moral, religious. Never before have they so needed actual contact with the world, needed to take personal part in the social, economic and political conflicts that are certainly determining now, over again, whether the country, this time both north and south, shall be free or slave, oligarchy or true democracy. The colleges have been able to forget, they have revolved about in a beautiful utopian individualism of class culture and personal salvation until the universities, the trade unions, the socialistic propaganda, the muck-raking magazines and even the yellow journals have called it to their attention—they have been able to forget that humanity crucified on a reckless industrialism is as tragic a thing as Christ crucified on the cross. We must have pragmatism of service to balance pragmatism of truth. In both cases that is worth while *which works*. Personality is much, loyalty and integrity are much, but neither personality, nor integrity, nor broad loyalty, can develop properly in the absence of capacity to see all the elements of modern life in something like their true values, amid the shifting lights of a rapid and complex evolution. True scholarship would help to develop this capacity. It would bring us nearer to seeing life clearly and seeing it whole—and truthfully.

The faculty makes the college. Scholarship and experience make the faculty. But scholarship and experience depend in the long run upon wealth and income. They have their material basis in the dollar. Even in education we can not escape the economic foundations of history. The American public can have just as good colleges as it is willing to pay for; and if it is willing to pay reasonably for efficient service here, as it pays lavishly elsewhere, it will find that nowhere else does a dollar purchase so much real utility. The public is abundantly able to pay for better colleges. It simply has not realized that the development and maintenance of ability costs money; nor has it yet a sufficiently high ideal of what the college should be and do. Least of all have many of the colleges themselves the right idea of what makes a real college.

THE UNIVERSITY IN POLITICS

By Professor T. D. A. COCKERELL

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SEEKING to define the functions of a university in a few words, I have thought that we might say: *the purpose of a university is to conserve useful truth and to add to it.* It should be in some sort the axis of our intellectual and moral growth, whence proceed the flowers and fruits of achievement. This is, of course, claiming a great deal for the institution, but it must be remembered that currents flow both ways, and the so-called product of the university is really the outcome of all human progress. Perhaps a homely illustration may serve our purpose. On pleasant evenings one may see the inhabitants of suburban districts engaged in watering their gardens. Superficially, they seem to hold in their hands useful little machines, from which, by a light pressure of the fingers, they are able to project sprays of water, strong or weak, straight or spreading, at their pleasure. Now we know that the water comes from a great reservoir, and the amateur gardeners have nothing to do with its origin or the force with which it escapes from their pipes, beyond, indeed, contributing their share of the water-rates. Nevertheless, from the standpoint of practical gardening, a mere deluge of water, unguided in its application, would be worse than useless; consequently the pipe, the nozzle and the gardener are essential factors for any kind of success. The university would be nothing without the great reservoir of accumulated human knowledge and experience. From this it draws its material and its energy, and yet not altogether so, for its own members, day by day, contribute intellectual capital. Literally construed, our analogy of the gardener probably breaks down in every case, because there is something creative in all human activity, though it may be, and perhaps usually is, reduced to a negligible quantity. Broadly speaking, however, the resemblance is sufficient for the purposes of argument. The university is, as it were, a nozzle through which flows, under the influence of human volition, the directed and organized output of man's mental activity. In the case of the gardener, very much—in one sense everything—depends upon his judgment, his ability to direct the water where it is needed, and in the best manner. It is even so with us. I have in the definition above not said merely that the university is to conserve truth, but *useful* truth. An intensely selective process is implied, and for this the power of judgment. Thus another definition is equally valid: *the purpose of the university is to cultivate judgment.* The untrained individual will carelessly neglect, wantonly throw away, the most precious things because he is deficient in this quality. Without judgment it is impossible to conserve and add to *useful* truth, from sheer inability to distinguish what is useful. What is the criterion of utility? Simply the common sense one, a useful truth is one which will serve some purpose, one which has pragmatic ability. We may go deeper than that, however. What purpose can truth serve? Obviously to join with other truth in a system of ideas. There is, as it were, a sociology of thought, a cooperative commonwealth of the mind, not unlike that exhibited by human society, and strictly parallel with it in development. Now in society, where all may share in the fruits of the intellect of the few, numbers and variety are necessary; so is it also with the mind, and thus judgment is not an esoteric ability conferred at random on pensive souls, but is dependent for its very livelihood on sufficient and diverse knowledge.

According to the description we have given of university functions, it must be apparent that the relation between foci of learning and public affairs is fundamental. Knowledge and judgment are the very qualities which necessarily determine the success of a politician in any broad and lasting sense. A successful public man is one who efficiently serves public ends; no other definition is possible, although, according to it, some current motions of success may be reversed. Many there are who unquestionably are successful, and likewise are public men; so there are great fools who are also men, but we do not call them great men. I think we may say without contradiction that the things the university stands for are precisely those most valuable in genuine politics, as distinguished from the mere struggle between predatory interests.

Here it will occur to many that academic bodies are somewhat arrogant, in the face of the fact that so much good knowledge and admirable judgment has resided and does reside in persons who have never been subjected to college influences. Such criticism is justly directed against claims occasionally made, but broadly speaking it has no foundation. The university is an intellectual focus, just as the church is a religious one, and from each the light spreads in all directions. It is not possible to say just where either begins or ceases. Legally, it is true, the university is a definite corporation, with particular precisely indicated members. Spiritually, intellectually, it is nothing more than the nucleus of an intellectual nebula; which nebula, in fact, is world wide, with as many nuclei as there are centers of learning, whether represented by buildings and charters or not. Thus to be a citizen of the university is ipso facto to be a citizen of the world, and the custom prevalent in some European countries of addressing all co-workers in one's subject as "dear colleague" is abundantly justified. So the university need not be ashamed to make large claims, always provided that it is really a place of intellectual and moral activity, and not a mental vacuum concealed by handsome buildings.

Many, substantially agreeing with what has been said, will declare that the university should *not* be in politics, because it cultivates knowledge and judgment, for others to *apply*. It is also often said that university professors are not practical men of affairs, being absorbed in their studies, while the world goes by unheeded. Taking the last statement first, we must confess that there is something in it. It is possible for a specialist to be doing splendid work, of the greatest advantage to mankind, without having any clear idea of the ultimate application of his discoveries, much less those in other fields. On the other hand eminent specialists are sometimes distinguished, like Huxley and Virchow, for their broad grasp of social questions and great services as publicists. Aside from these considerations, however, is the fact that the university is in a sense an intellectual baby-farm, and the infant ideas nourished there are many of them not yet ready to go out in the world and do their day's work. It is about as just to complain of the inutility of new truths as it would be to blame mothers of young children in time of war, because of failure to contribute members to the army.

There is, however, one quality of great public value in which scientific men are admittedly as preeminent as the majority of present-day politicians are deficient. This is the power, or the habit, of forming so-called impartial judgments, that is, judgments based on the available evidence, not dictated by partisan or personal desires. We are only just beginning to realize that men of this class will be widely useful in the guidance of the ship of state, bringing about the transformation of much that is undesirable in the life of this nation. It is not expected that every scientific man will offer opinions on every subject; precisely because he has the quality referred to he will refuse to do this; but when he feels competent to express an opinion, after due research, it will be worth more in the consideration of the tariff, the treatment of the Filipinos, or the question of railroad regulation, than that of any political boss who ever lived. This opinion will not be impartial, in the sense of being colorless rarely will the expert desire or contrive to sit gracefully on the fence, but it will bring to a focus the best results of human thought as applied to the matter in hand. Against all this will be cited the well-known saying that "doctors disagree." You can find an "expert," people say, to declare anything. It is true that on many important scientific questions eminent workers differ greatly, but when this is the case, those questions are considered still open for discussion. It is one of the merits of science, as against partisan politics, that she does not feel obliged to decide everything as though by infallible judgment. Many things are still in the experimental stage. It should be stated, however, that most of the alleged experts who muddle the public mind are partly or wholly pseudoscientific. A very small amount of inquiry among the citizens of the real republic of science would demonstrate this to any one.

Thus, I think the members of any university faculty should be "in politics" to the extent of being ready and anxious to help wherever they can, to come forward and fight for what they believe to be true and wise. They should also, it is almost superfluous to say, stand always for the moral and decent thing. On the other hand, speaking for myself, I do not see how any man with scientific training can be a strictly "regular" member of any political party. In some particular controversy, he may be wholly on one side, but in the long run, orthodox party service deprives him of that freedom of judgment and action which he deems so essential. Fortunately, everything indicates the breaking up of the old rigid lines; not, I believe, so much to form new ones along fresh directions of cleavage, as to allow greater freedom for the products of honest thought. Thus the initiative and referendum, by compelling people to form judgments on particular questions, will prove well worth the expense and sometimes inconvenience they may occasion.

What about the student body in politics? Its members are young and relatively inexperienced, but they are, we hope, to be the politicians of the future. They ought, at any rate, to be in training for public service. Probably the greatest criticism that future generations will make on our present educational system is this, that thought and deed are too far apart; so far, often, that the deed never follows. Every one deplores the lack of earnest purpose shown by so many university students, and many attribute it to an absolute deficiency in the individuals concerned. Much of it, I fancy, is due to nothing more than lack of opportunity to do things; an opinion confirmed in part by the extraordinary activity shown from time to time in foolish undertakings, and in part by the excellent record in life of many men who were never considered very able in college. It is in many ways a difficult situation, yet I confess I should be willing to see our students more active in public affairs, more like those men of the universities who have always taken prominent parts in political crises in Germany. To some extent the faults of immaturity are offset by the fresh and generous attitude of one who goes to battle unwounded and unafraid. I remember how a certain writer once rejoiced that he had, when a young man, written a book. It was bold to the point of error, he would not, could not, write so now—but, after all, it had a precious quality he could never again approach.

The internal activities of the university afford scope for a good deal of political talent, but unfortunately their purposes are often petty, and their conduct sometimes reflects all too well the method prevalent in "real" politics outside. Here again, no doubt conditions are improving, and the time may come when even the most insignificant matters afford scope for the development of habits and points of view of the utmost moment. We have also the civic clubs, really entering into the national arena to some extent, and already doing valuable public service.

In all of this, we shall reap approximately what we sow. If, in some countries learning and possibly virtue are more highly esteemed than in our own, it is the work of those who have stood for learning and virtue, year after year, month by month, day by day. These things will not come without conscious and long-continued effort. I feel that in our anxiety for material support, we sometimes forget the essential things. It is good to have money, it is delightful to see a large and growing student body, but whatever comes of it, let us always refuse to sell our birthright for even the largest, most attractive mess of pottage.

THE CLASSIFICATION OF THE SCIENCES

By Dr. IRA WOODS HOWERTH

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THE sciences are divided by Spencer, Karl Pearson and others into two great groups, the abstract sciences and the concrete sciences. The abstract sciences are those which deal with the modes under which the phenomenal world is perceived. They have to do entirely with the "relations of co-existence and sequence in their general or special forms."[1] Mathematics and logic are the two main branches of this division of the sciences.

It has been suggested by Comte, and insisted upon by Professor Lester F. Ward,[2] that mathematics and logic are not true sciences, but merely "forms" or conditions of science and aids to its study. We need not here concern ourselves with this question. Our interest is rather in the classification of those sciences which deal with phenomena themselves rather than with the modes under which they are perceived, that is, the concrete sciences.

The classification of the concrete sciences may proceed, of course, from any one of a number of bases, as the chronological order of their development, their logical relationships, the evolution of their subject matter, etc. Bacon's classification is based upon three assumed faculties of our understanding—memory, imagination and reason; and Comte's classification rests upon the order in which the subject matter of the various sciences has been evolved. The latter is the basis of the classification we are about to propose.

The first consideration, then, must be the order in which the great natural groups of phenomena have manifested themselves in creation, that is, in the great evolutionary process.

Evolution has been described as that view of the universe which assumes that a vast, uniform, uninterrupted process of development obtains throughout all nature; and that all natural phenomena without exception, from the motions of the heavenly bodies and the fall of a rolling stone to the growth of plants and the consciousness of men, obey one and the same great law of causation.[3] Science, to be sure, has

[1] Spencer, "The Classification of the Sciences," "Essays," Vol. III., p. 10.

[2] See Ward, "Dynamic Sociology," Vol. I., p. 106; also "Applied Sociology," p. 306.

[3] Haeckel, "Freedom in Science and Teaching," Chap. I. (Humboldt edition, p. 10).

not yet closed up to the satisfaction of all the gaps in this process, but its "uninterrupted" character will hardly be denied by any one to whom this discussion will be of interest. We may assume that the principles of uniformity and continuity in evolution have been established.

Now the general process of evolution may be roughly divided into cosmic, organic and social; and it will not be denied that organic evolution has succeeded cosmic, and social evolution, organic. There are here presented, then, three great classes of phenomena in their genetic order; and not only that, but also three great divisions of the forces which occasion these phenomena, and three groups of sciences of which these phenomena are the subject matter. We shall now proceed to analyze the forces which produce these three kinds of evolution.

Cosmic, or inorganic, evolution involves three kinds of changes—atomic, molecular and molar. There are accordingly in this department of evolution three sets of causes. These causes are forces to which we may ascribe the names atomic, molecular and molar. Changes which take place in the organic process are vital and mental; or, as we prefer to call them and the forces which give rise to them, biotic and psychic. The biotic forces are those which occasion the phenomena of life, and the psychic forces those which occasion the phenomena of mind. Finally, the phenomena of the social world must owe their causal relationships to forces which may be grouped under the general term social. We have, then, the forces of the phenomenal world analyzed into the atomic, the molecular, the molar, the biotic, the psychic, and the social forces.

It is important to observe that these various kinds of forces are not coeval, but have been successively brought into existence by the process described by Professor Ward[4] as synergy. As a beginning of the evolutionary process, we may assume atomic attraction and repulsion, atomic collision, elective affinities—that is, atomic forces, and atomic forces only. Other forces had no existence in nature except as potency. It seems obvious enough that there could be no molecular forces until the molecule was built up, no molar forces until molecules were combined in masses, no biotic or vital forces until living matter was brought into existence, no psychic forces until mind appeared, and no social forces until the formation of the social group. Thus the various realms of forces here suggested are coeval and co-extensive with an equal number of great and well-defined fields of phenomena. No phenomena without change, no change without force. To these fields of phenomena we may now turn our attention.

To the changes of phenomena occasioned by atomic forces the name chemical is applied. Chemical change, so the books say, is one which

[4] See Ward, "Pure Sociology," p. 171 et seq.

does not destroy the specific identity of a substance. To a change which does destroy this specific identity we apply the term physical. This is, of course, a narrow use of the term, but it is in accordance with past usage. Chemical phenomena are, then, the phenomena produced by chemical forces, and physical changes are those produced by molecular and molar forces. Chemical phenomena are first in order of time. "In the beginning" were atoms, atomic forces, atomic changes, chemism.

The second order of phenomena are the physical. They include the movements of molecules and masses from the invisible compounds of atoms to the great aggregates of matter in suns and stars. They are the natural outgrowth of chemical changes. Cooperating with the chemical forces the physical produced organic matter, protoplasm, and thus initiated the third great natural group of phenomena, the biological. Biological phenomena, which are the manifestation of the biotic forces, include, of course, the whole range of phenomena between inorganic nature and the origination of mind. Mind, we must assume, was also the creation of the preexisting forces, and the manifestations of mind, or psychic phenomena, constituted the fourth great division of phenomena. Finally, beginning with the origin of social groups, we have the constantly extending field of phenomena known as social, a direct manifestation of the social forces.

We have now presented a classification of forces and phenomena based on their genetic relationships. This, it will be observed, is equivalent to the classification of possible knowledge concerning concrete phenomena. It is thus a classification of the sciences. For a science is a study, or the classified knowledge resulting from the study, of a definite field of phenomena occurring in natural sequence as a result of a particular set of forces. Our classification of forces and of phenomena in their genetic order is, then, in reality a serial or genetic classification of the subject matter of the sciences. "Sciences," says Ward, "in so far as they can be grouped at all, simply represent the natural groups of phenomena, and to determine the natural order in which phenomena are related to one another as indicated by their respective antecedence and sequence in the march of evolving forces, is to determine the natural order in which the sciences stand to one another."[5] The respective fields of forces and phenomena as already classified, then, imply corresponding sciences. There are five such fields, namely, chemical, physical, biological, psychological and sociological. Hence there are five great sciences: chemistry, physics, biology, psychology and sociology; and unless phenomena do not arise in the order stated above, this is a classification of the sciences which implies their genetic relationships and their relations of dependence. It is the order, too, of increasing

[5] "Dynamic Sociology," Vol. I., p. 147.

complexity. The phenomena and forces of each science appear in all the sciences which succeed, but not in those which precede, it in the scale. Each science is thus engaged in the study of a new set of forces and phenomena. The order of the sciences here stated is, therefore, the order of increasing complexity and diminishing generality.

The foregoing classifications of the evolutionary process, forces, phenomena and sciences may be resumed in the following table:

Evolution	Forces	Phenomena	Sciences
Cosmic	Atomic Molecular Molar	Chemical Physical	Chemistry Physics
Organic	Biotic Psychic	Biological Psychological	Biology Psychology
Social	Social	Sociological	Sociology

It is not necessary to contend or assert that the forces of the various fields of phenomena, and the consequent extent of the respective sciences are, or ever can be, as sharply defined as the foregoing discussion might seem to indicate. The possible overlapping of the fields of phenomena and the corresponding sciences should be indicated in the table by an arrangement of braces connecting them.

Chemistry, physics, biology, psychology and sociology are, then, the five great divisions in a comprehensive classification of the sciences. They are the five great stems or branches out of which all the other and more special sciences necessarily develop. There is no true science which may not be subsumed under one or the other of these general sciences.

Let us now compare the foregoing classification of the sciences with others, particularly those of Comte and Spencer. Comte's well-known "hierarchy" of the sciences includes the following: mathematics, astronomy, physics, chemistry, biology and sociology. Spencer includes in the concrete sciences astronomy, geology, biology, psychology, sociology and ethics. As already observed, Comte indicated a belief that mathematics is not a true science. It should also be noticed that he gave to biology a wider meaning than is ordinarily ascribed to it. He included what he called "transcendental biology," by which we may understand cerebral biology or psychology. He also, in his later writings, made ethics the final term of the series. His classification needs to be rearranged before a comparison is made. This rearrangement has been made by Professor Ward in a comparison of the classifications of Comte and Spencer. For convenience in comparison, we shall place the classification of Comte, Spencer and the one proposed in parallel columns:

Comte's Classification	Spencer's Classification	Proposed Classification
1. Astronomy	1. Astronomy	1. Chemistry
2. Physics	2. Geology	2. Physics
3. Chemistry	3. Biology	3. Biology
4. Biology	4. Psychology	4. Psychology
5. Cerebral biology	5. Sociology	5. Sociology
6. Sociology	6. Ethics	
7. Ethics		

It will be observed that beginning with biology all three classifications are the same, with the exception that Comte and Spencer include ethics as a science coordinate with others of the group. If it properly belongs there it must have a special field of phenomena occasioned by a special set of forces coordinate with the social forces. But ethical forces and phenomena are occasioned by the social forces; hence ethics, as Professor Ward has pointed out, is only a department of sociology.

The chief difference between the proposed classification and those of Comte and Spencer lies in the divisions preceding biology. Astronomy with both Comte and Spencer is the first great division of the sciences. But to make astronomy the first of the sciences in a genetic classification is to imply that the subject-matter of astronomy is at the beginning of the creative process. Stellar phenomena, however, must have been preceded by both physical and chemical phenomena. Instead of being first and coordinate with other great sciences astronomy is properly a subdivision under physics. This is sometimes indicated by the application to astronomy of the names astro-physics, or celestial physics. Since it seems that stellar phenomena properly belong to the field of physics and chemistry, we are obliged to omit it from the classification as one of the great general sciences.

In Spencer's classification geology is placed second in the list. This is surely unwarranted. Geology, the study of the earth, is no more coordinate with chemistry, physics, biology, psychology and sociology than is the study of Venus, Mars or the moon.[6] Geology, then, like the science of any other planet, properly belongs under astronomy.

The remaining and perhaps the most fundamental difference of the proposed classification from that of Comte is that in the former chemistry precedes physics. Bacon called physics the "mother of the sciences." Haeckel also, in the concluding chapter of his "Wonders of Life," speaks of physics as the fundamental science. In the fourth chapter of the same book, he writes as follows:

> The study of the atoms and their affinities and combinations belongs to chemistry. As this province is very extensive and has its special methods of research, it is usually put side by side with physics as of equal importance; in reality, however, it is only a branch of physics—chemistry is the physics of the

[6] This is the opinion also of Professor Ward. See "Pure Sociology," p. 69, footnote.

atoms. Hence, when we speak of a physico-chemical inquiry or phenomenon we might justly describe it briefly as physical (in the wider sense).[7]

But "in the wider sense" all natural phenomena are physical. Thus we have the psychophysics of Fechner and Weber, and the social physics of Comte and Quetelet. Comte classed chemistry as one of the divisions of terrestrial physics, as if chemical phenomena were limited to the earth! In our classification we use the term physical in the narrow sense, and the science of physics is regarded as dealing with the molecular and molar movements of matter, that is, with physical changes no matter where they take place. These changes are preceded in the evolutionary process by the phenomena due to atomic affinities and combinations. Chemistry, therefore, should precede and not follow physics in a comprehensive genetic classification of the sciences. We thus make it first in the order of our classification, since its phenomena and forces are first in the order of time.

It would be interesting, perhaps, to continue farther an analysis of the sciences in order to show where some of the more familiar of the special sciences belong. Chemistry obviously falls into the two divisions, inorganic and organic. Physics may quite as obviously be divided into molecular and molar physics. The former division includes such sciences as thermology, electrology, etc., while under the latter, since it includes the study of all phenomena occasioned by the gravic forces, must necessarily fall such sciences as barology and astronomy, or at least that part of astronomy known as astrophysics. Geology, the science of the earth, a planet, belongs properly, as was said before, under astronomy. The general science of biology is the synthesis of four great special sciences, namely, protistology, phytology, zoology and anthropology. Psychology is individual and social. Finally, sociology should fall into the special sciences of the respective social groups, but the terminology is wanting. The special social sciences, as, for instance, history, politics, political economy, jurisprudence, etc., while they properly belong under sociology, are coordinate so far as the respective fields of their phenomena are concerned, and are consequently not subject to arrangement on the basis of their own genetic relationships.

It would be difficult, however, if not impossible, to arrange diagrammatically the special sciences without cumbersome repetition, even if one possessed the requisite knowledge. Each branch of a science may be a contributor to a special science. Each division of biology, for instance, has its own morphological and physiological sciences. An attempt at such an arrangement, with existing scientific nomenclature, would involve extensive neologism.

[7] Haeckel, "The Wonders of Life," New York, 1905, p. 88.

FRANCIS GALTON

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TO the man of affairs the progress of science must seem monotonously methodical. Should he walk through the scientific section of a great library he would find massive walls of books, journals and learned transactions, and would note that year by year the tomes of which these walls are built up become a little thicker and that new and more specialized series are interpolated among the old.

Blowing the dust from the tops and cutting pages here and there he would soon find himself completely confused. Nowhere would he be able to turn down the page corner and say, "This is fundamental: this represents a real step forward: this is one of the milestones in the advance of science."

Those who are not visitors in the stacks but work there, know that except in the accumulation of facts the growth of science has by no means been a movement of uniform acceleration. Most scientific investigators are imitative, contributing to detail but setting no new landmark on the horizon. Now and then, however, a man of keener imagination and clearer mental vision sees a new and attractive region for exploration and blazes a trail. Sometimes the new field is reached after great effort, sometimes only an easy ridge has to be crossed. Others at once follow his leadership, clearing, mapping, describing and illustrating. The work of both is essential, but the one we honor as an explorer and the other we respect as a surveyor. Most men of science are surveyors merely.

On January 17, 1911, one of the great explorers, both literally and figuratively, laid down his active work in the sciences and humanities. Had death come a quarter of a century ago, scientific men would have mourned the loss of an able colleague. To-day, sadness can not be limited by the boundaries of the divisions of the many ologies, for the world has lost another of the great Victorian minds, the peer of Huxley, Spencer and his own cousin, Charles Darwin; yet regret must be tempered with a profound thankfulness that a life so rich in achievements and in personal influence could be granted the full term of nearly ninety years. Twenty-five years ago, Mr. Galton had already contributed his "Tropical South Africa" and the "Art of Travel" to the literature of geographical research. His inventive genius and mechanical ingenuity had been telling factors in the nascent science of meteorology. Human faculty in various phases had interested him, and as early as 1869 he had published the great work entitled "Hereditary Genius," and in "Inquiries into Human Faculty" of 1883, he had suggested the term eugenics for the science of race improvement, and had advanced strong arguments in favor of its practicability.

Had 1885 instead of 1911 staid his pen, we should have been deprived of "Natural Inheritance." We should have lacked his greatest contribution to scientific method—one of the most powerful tools of research—the correlation coefficient. Criminologists would have missed his contribution of the finger print method of identification. Biometry would have wanted his personal stimulus and support which has counted so much in the development of the new science. Humanitarians would have had to wait from another not only the initiation of comprehensive quantitative investigations of the relative significance of heredity and environment—of nature and nurture, as he happily expressed it—but also the courage to urge the possibility of the improvement of the human stock under present conditions of law and sentiment.

Ancestry and Training

One of Galton's great problems, that concerning the relative importance of nature and nurture in determining the characteristics of the individual, might be hard to solve from a study of his own family history.

When one is told that Francis Galton and Charles Darwin were both grandsons of Dr. Erasmus Darwin, and learns the mental traits and physical powers of other direct and collateral ascendants, he is ready to cast the ballot at once for inheritance, or nature. But when one opens the delightfully written "Memories of My Life" and reads of his home life and of his contact with profound and alert minds in hospitals and at Cambridge, one hesitates and wonders whether environment, or nurture, should not be credited with a substantial share of his greatness.

In human families, however, nurture is largely a product of nature. It was not by accident that Samuel John Galton, the manufacturer and contractor, grandfather of Francis Galton, was associated with such men as Priestley, Dr. Erasmus Darwin, Keir the chemist, Withering the botanist, Watt and Boulton. So in the other associations of the family, one can see ability seeking its like; while his attainments may be in part due to economic independence and propitious environment it must be also borne in mind that independence and environment are in their turn referable to the innate ability of the stock from which he came.

The greatness of the man is attested by the facts that there was a minimum of training and a maximum of accomplishment, and that as in the case of many other intellectual leaders it is impossible to differentiate clearly preparation and life work. In some of our institutions a man eager for research in any field must have his enthusiasm smothered and his personal ingenuity choked down by all of the minor requirements for the gilt seal of the university degree. Independent of the university stamp Mr. Galton spent his youth using his eyes and mind while working with the best men he could in hospitals and at Cambridge, where owing to a serious breakdown in health he contented himself with a poll degree instead of reading for mathematical honors. Throughout life the discipline which made possible the next and greater task yielded its own contribution to science. Days and nights in wards demand keenness of observation. This and his early travels in Egypt and Syria prepared him to be a scientific explorer instead of merely a gentleman sportsman bagging big game in tropical Africa. His fascinating book on Damara and Ovampo Land gave him the scientific standing of a gold medalist of the Royal Geographical Society in 1853, but his "Art of Travel" which grew naturally (for a man of Mr. Galton's type of mind) out of his Syrian and African experience perhaps counted for more in the advancement of geography. The one contained its own quota of concrete facts; the other served to instruct others in the art of exploration. First-hand experience with clinical thermometers, practical use of sextants in the wilderness and early experiments with a printing telegraph are good preparation for an active part in the work of the standardization of instruments and of the development of methods for the publication of meteorological data. Human faculty and heredity are closely linked together, and from heredity to eugenics is only a short step, and one forced upon the man who goes deeply into the former.

Some of the reminiscences of the period of training which have been given us in the "Memories" are interesting even to those whose lives go back to the early days of modern medicine.

His life as indoor pupil in the Birmingham General Hospital began in the fall of 1858.

> The times of which I am speaking were long before those of chloroform, and many years before that of Pasteur and Sir Joseph Lister. The stethoscope was considered generally to be new-fangled; the older and naturally deaf practitioners pooh-poohed and never used it.

Once a powerful drayman was brought in dead drunk with both of his legs crushed and mangled by a heavy wagon.

> They had to be amputated at once. He remained totally unconscious all the time, and it was not until he awoke sober in the morning that he discovered that his legs were gone. He recovered completely. The question that then presented itself to me was, "Why could not people be made dead drunk before operations? Could it be effected without upsetting their digestion and doing harm in other ways?" The subsequent discovery of inhaling instead of drinking the intoxicating spirit, whether it be chloroform or ether, solved that question most happily.

Writing of student days at King's College where, or at the home of Professor Partridge, he came in contact with such men as Dasent, Daniell, Todd, Smee and Wheatstone he says:

> The signs of advance were all about and in the air. The microscope had rather suddenly attained a position of much enhanced importance; it was now mounted solidly, with really good working stages and with good glasses. Powell was the principal maker of it, and a Powell's microscope was an object almost of worship to advanced students.

The impression from his first work in Trinity College, Cambridge, in 1840 are worth quoting for those interested in education,

> I soon became conscious of the power and thoroughness of the work about me, as of a far superior order to anything I had previously witnessed. At the same time I wondered at its narrowness, for not a soul seemed to have the slightest knowledge of, or interest in, what I had acquired in my medical education and what we have since learnt to call Biology. The religious dogmas were of a more archaic type than I had latterly learnt to hold. I thought that just as the medicals wanted the thoroughness of the classicals and of the mathematicians, so these wanted at least an elementary knowledge of what was familiar to the medicals. Great and salutary changes have long since been introduced, and the above criticism, which was perfectly just at the time, is now, I believe and trust, almost wholly out of date.

It is perhaps fortunate that in 1840 Galton found his knowledge of chemistry and German hardly sufficiently advanced for him to profit by Liebig's teaching in Giessen, for the spirit of travel was strong within him and he "determined to throw that plan over, to make a dash and go as far as my money allowed." This dash carried him from Giessen to Linz, thence by rowboat to Vienna, by steamer down the Danube, overland to the Black Sea, to Constantinople, Smyrna, Syra, Trieste and home by way of northern Italy and Switzerland. "This little expedition proved to be an important factor in moulding my after-life. It vastly widened my views of humanity and civilization, and confirmed aspirations for travel which were afterwards indulged."

The next lesson in travel was a journey up the Nile, where by good fortune one Arnaud Bey urged him not to be content with the attainments of ordinary tourists but to strike overland by camel in the caravan of the Sheikh of the Bishari Desert to Berber.

> A caravan yields so many strange experiences and affords so many occasions of mutual helpfulness and of friendships, that it is easy to understand the importance of the Hadj pilgrimage in hunting the Moslems. I have often wished that something of the sort could be revived among ourselves, such as the famous Canterbury Pilgrimage of Chaucer, but the religious motive for real pilgrimages is generally wanting in Protestant countries. The congresses of large itinerant societies like the British Association, in some few respects may be considered as taking the place of pilgrimages, but they want the long hours and days of open-air life, hard exercise and leisure.

From Berber a boat was hired to work up to Khartum and from thence a short excursion was made up the White Nile. Later his path led him through Syria, and back to England where hunting and shooting, extensive reading and digesting what he read by much thinking about it, completed what we have for convenience differentiated off as the period of training.

The only published paper of this period was a pamphlet, entitled "Telotype, a Printing Electric Telegraph." The following sixty odd years of his life were to be devoted to productive work in the most varied branches of science.

Exploration and Geographical Science

In an atlas of to-day the white areas on the map are very small in comparison with those which are meshed with the highways. The editions in 1849 were very different. "It was a time when the ideas of persons interested in geography were in a justifiable state of ferment."

The journey up the Nile and into the Soudan had been "a tour hastily performed, but sufficient to imbue or poison me with the fascination for further enterprise, which African tourists have so especially felt—a fascination which has often enough proved its power by urging the same traveler to risk his comfort, his health and his life, over and over again, and to cling with pertinacity to a country which after all seems to afford little else but hazard and hardships, ivory and fever."

It was not merely the enticement of big game, of which wonderful stories had begun to come back to England, that attracted Mr. Galton to South Africa. Every chapter of his book, "The Narrative of an Explorer in Tropical South Africa," bespeaks keenness of observation and solicitude for scientific precision. It can not be abstracted here, neither can space be spared for quotations to show its literary charm. The difficulties of the journey are summarized—and very modestly—in the last chapter.

> Christmas and New Year's day had passed, when early in January, 1852, as the morning haze cleared away, the sails of a schooner loomed large before us; in a moment I was in my pontoon and paddled out to her, jumped on board, and received my letters of a year and nine months' interval. They were not indeed unchequered by melancholy news; but for the intelligence they conveyed of my own family circle I had every reason to be grateful. Thus closed my anxieties and doubts. I had much indeed to be thankful for. I had not lost one of my many men either through violence or through sickness in the long and harassing journey I had made. It was undertaken with servants, who, at starting, were anything but qualified for their work, who grumbled, held back and even mutinied, and over whom I had none other than a moral control. I had to break in the very cattle that were to carry me, and to drill into my service a worthless set of natives, speaking an unknown tongue. The country was suffering from all the atrocities of savage war when I arrived, and this state of things I had to put an end to before I could proceed. All this being accomplished, I found myself without any food to depend upon, except the oxen that I drove with me, which might, on any evening, decamp or be swept off in a night attack

by the thieving and murderous Damaras. That all this was gone through successfully, I am in the highest degree indebted both to Andersson and to Hans, for single-handed, I hardly know what I should have done.

The importance to geography of this exploration of the countries of the Namaquas, the Damaras and the Ovampo is perhaps best described in the words of the president of the Royal Geographical Society, Sir Roderick Murchison, in presenting its gold medal to Mr. Galton in 1854.

You have accomplished that which every geographer in this room must feel is of eminent advantage to the science in which we take so deep an interest. Accept, with these expressions, my belief that, so long as England possesses travelers with the resolution you have displayed, and so long as private gentlemen will devote themselves to accomplish what you have achieved, we shall always be able to boast that this country produces the best geographers of the day.

On his return Mr. Galton threw himself into the work of the Royal Geographical Society. Those were days when geography required explorers, not surveyors. The reports of snow-covered mountains in eastern Africa were fiercely criticized by some and only half credited by others. The source of the Nile was a subject of bitter controversy. The Congo had still to be explored. During the half century, more or less, that he was officially connected with the work of the society Mr. Galton had much to do with the chief figures in African exploration—Speke, Burton, Grant, Baker, Livingstone and Stanley. An interesting chapter is given to these matters in the "Memories."

Science has probably not lost by the impaired health which precluded further exploration. Syria, Egypt, the Soudan and tropical South Africa had yielded the first-hand experience which made possible the collating and sifting of the work of others and the moulding of it into a compact compendium.

On reading the narrative of the explorations in tropical South Africa one is impressed with the large place that is given to method. The breaking in of oxen, the seasoning of an axle tree, the making of a krall, the best way of carrying a gun on horseback were the things absorbing his attention. In his work in the Royal Geographical Society and in his contact with the majority of the prominent explorers he saw the opportunity of executing the task which he had conceived while in the South African brush, and the "Art of Travel" was issued in 1854. Darwin was a good prophet when he wrote, ". . . what I fully expect is that it will have a long sale," for at least four editions have been issued.

"The Art of Travel" is a truly remarkable book. Its conciseness, clearness and comprehensiveness must be judged from its own pages, not from those of a review.

Some of the fellows of the Royal Geographical Society are now feeling a keen satisfaction in the work which the society has done to advance geographical teaching. In the initiation of this movement for a larger place for the science of geography in education Mr. Galton had a pioneer part. First the public schools were interested in annual competitions for gold and bronze medals to be awarded for the best papers in the competitive examination. This not only interested the students, but it also showed up for correction weaknesses in the current instruction. Later the problem of geography in the university was taken up, and it probably has now a firm foothold at both Oxford and Cambridge.

Physical Sciences and Meteorology

Francis Galton's contribution to the physical sciences, conventionally so called, was not large. We find no paper on chemistry, and those of a physical or mathematical character impress one as the recreations of a brilliantly ingenious amateur rather than the wood hewing and the water drawing of the trained and speciality limited professional. It would be hardly fair to quote as examples of his work in this field such experiments as those with spectacles for divers or stereoscopic maps for tourists, although these may be in a way illustrative for ingenuity. Neither can his printing electric telegraph or his suggested principle for the protection of riflemen be regarded as strictly typical. These do not seem to belong on the same thread as the other contributions which are to be spoken of in this section. This thread is the unity and perhaps unconscious seriousness of purpose to secure greater exactness in fields where only rough description had hitherto been thought possible.

The work of Kew Observatory, widely known among physicists, offered an attractive field of activity for a man of Mr. Galton's tastes. He was associated with the work of the institution for many years before he became its chairman in 1889, to continue in this post until the observatory was merged in the National Physical Observatory in 1901.

Among the problems which occupied him there were the standardization of sextants, and other angular instruments, and the rating of watches and the rapid verification of clinical thermometers.

The laws of the weather were at that time beginning to attract serious attention. The collection of numerous simultaneous observations demanded the development of self-recording instruments; in this work he also had a share. Particular credit is due to him for the first charting of the weather.

As early as 1861 he pointed out the needs of presenting the meteorological conditions observed over a given region graphically and published an illustrative map. This first map which we may recognize as the progenitor of our daily weather map, was printed from moveable type, especially designed for the purpose. Later many experiments were made with different devices for engraving plates from which the meteorological charts might be printed. In 1863 he published a volume of charts under the title "Meteorographica." He was a member of the Meteorological Committee (later Meteorological Council) formed in 1868 for the purpose of giving storm warning to seaports, for obtaining data for marine charts, and for maintaining a few observatories with self-recording instruments. His service during the thirty years that he was connected with the work of the committee and council may be best expressed in the words of Sir Richard Strachey, in a letter written to Mr. Galton on his retirement from the council in 1901. Only a paragraph can be given.

It is no exaggeration to say that almost every room in the office and all its records give unmistakable evidence of the active share you have always taken in the direction of the operations of the office. The council feel that the same high order of intelligence and inventive faculty has characterized your scientific work in meteorology that has been so conspicuous in many other directions, and has long become known and appreciated in all centers of intellectual activity.

Composite photography may be mentioned here, although in explaining its origin we must refer to matters more properly belonging to a subsequent section.

The blending of physiognomies by allowing each to make upon the sensitive plate but a fraction of the impression required for a clear picture may in the hands of some be only a harmless amusement for the scientific amateur, but the mother of this invention was the necessity for the securing of greater precision in the determination of family, class or racial types. Composite photography is the mechanico-graphical method by which its inventor attempted to solve the problem. He points out that human features must show great differences, since we are able to recognize a familiar face among thousands. This is possible because the general expression of a face is the sum of a multitude of small details which are viewed so quickly that they are apparently taken in at a single glance. If any difference from a remembered face be present it immediately looms large before the eye and overshadows all the many points of resemblance. It is impossible to measure these infinitesimal differences between individuals and to determine by statistical means what is the characteristic physiognomy of a race. The selection and photographing of "typical" or "representative" individuals—the course commonly adopted—is altogether untrustworthy, since the judgment of the observer is itself fallaceous, easily swayed by gross and exceptional features rather than by the ordinary ones, so that the carefully chosen typical portrait is more apt to be a caricature.

In a composite photograph family or racial characteristics are strongly impressed upon the film, while the individual idiosyncrasies average out—much as they do in statistical analysis—or to use Galton's own phrase, "leave but a ghost of a trace of individual peculiarities." To discuss in detail the practical applications which have been made, or which may probably be made of composite photography would lead us too far afield.

Biology and Biometry, Human Faculty and Heredity

When Charles Darwin's name was proposed before the French Academy for membership in the zoological section one of the immortals strongly opposed, and offered to put a hundred others before him because of their contributions of demonstrable facts.

Now whether Darwin is to be ranked as a zoologist or Galton as a biologist is one of those irrelevant questions the answer to which depends entirely upon definition. If biologist means only a worker in a historically fenced in field, then Mr. Galton has little claim to be known as a biologist. If, however, the term biology belongs to a living instead of a dead language and is capable of changing its meaning as men untrammeled by traditional barriers suggest new methods which broaden and deepen, if a man is to be judged by the directing influence he exerts as well as by the pages he publishes, then Francis Galton must take rank as a very great biologist indeed.

His South African narrative contains practically no observations on natural history of the kind generally found in works of exploration. Possibly this side of the work was left entirely to his companion, Charles J. Andersson, who was particularly interested in natural history, and afterwards continued observations and wrote on the region which they had opened up, for there are in Mr. Galton's book many keen observations on the behavior of his cattle. This interest in and capacity for detailed study of the behavior of animals is also evident in the "Art of Travel." A paper on "Gregariousness in Cattle and in Men" was published in 1872.

The only piece of work along at all conventional lines was his memoir on "Patterns in Thumb and Finger Marks," published by the Royal Society.

Experimental methods in biology attracted him. He wrote on experimental moth breeding as a means of verifying certain important constants in the general theory of heredity, and performed experiments to test the theory of pangenesis by breeding from rabbits of a pure variety into whose circulation blood from other varieties had been largely transfused. Thus forty years ago he undertook problems analogous to those which are now being attacked by quite a different method—namely by the transplantation of ovaries. Experimental studies in the inheritance of size of seed in sweet peas formed a part of the basis of his well-known law of regression.

If, as will be shown later, Francis Galton's great contribution to botany and zoology was that of method, the case is very different in that branch of biology which pertains to man.

The volume on South Africa attests a live interest in racial traits and racial competition. Between this and "Hereditary Genius" a period of sixteen years elapsed, during which the "Origin of Species" had appeared. Thus neither of these volumes was the product of a running pen. The book, he tells us, grew out of a purely ethnological inquiry into the mental peculiarities of different races.

"The theory of hereditary genius," Mr. Galton says in the preface, "though usually scouted, has been advocated by a few writers in past as well as in modern times. But I may claim to be the first to treat the subject in a statistical manner, to arrive at numerical results, and to introduce the 'law of deviation from an average' into discussions on heredity."

This is a late date to review a book like "Hereditary Genius." Some day it may take its proper rank alongside the "Origin of Species." If one wants higher praise than that in the "Descent of Man" he may read Mr. Darwin's letter.

DOWN, BECKENHAM, KENT, S. E.
3d December

My dear Galton:—I have only read about 50 pages of your book (to judges) but I must exhale myself, else something will go wrong in my inside. I do not think I ever in all my life read anything more interesting and original —and how well and clearly you put every point! George, who has finished the book, and who expressed himself in just the same terms, tells me that the earlier chapters are nothing in interest to the later ones! It will take me some time to get to these latter chapters, as it is read aloud to me by my wife, who is also much interested. You have made a convert of an opponent in one sense, for I have always maintained that excepting fools, men did not differ much in intellect, only in zeal and hard work; and I still think this is an eminently important difference. I congratulate you on producing what I am convinced will prove a memorable work. I look forward with intense interest to each reading, but it sets me thinking so much that I find it very hard work; but that is wholly the fault of my brain and not of your beautifully clear style.

Yours most sincerely,
(Signed) CH. DARWIN

In 1874 "Hereditary Genius" was supplemented by a little book entitled "English Men of Science, their Nature and Nurture." Abandoning a chronological sequence for the moment we may mention "Noteworthy Families" by Galton and Schuster, published in 1906. These two volumes supply "what may be termed a natural history" of modern English men of Science.

"Inquiries into Human Faculty" of 1883 embodied the supplemented essentials of papers which had appeared subsequently to "Hereditary Genius" of 1869, and which "may have appeared desultory when read in the order in which they appeared" but which had nevertheless "an underlying connection." Possibly the work falls somewhat short of his others, but it is fascinating and above all suggestive reading for the psychologist. Among the topics discussed, such as color blindness, capacity for distinguishing shrill sounds, criminality and insanity, gregarious and slavish instincts, mental imagery, number forms and color associations, only one may be noticed in further detail. This is a study of the sensitiveness of blind and seeing, savage and civilized individuals. As a result of his personal experience in barbarous and cultured lands, he concludes that savages have no keener senses than civilized man; and as a result of his experiments in schools for the blind he finds that the popular belief that in senses other than sight the blind are more sensitive than normal individuals has no foundation in fact.

After a lapse of six years "Natural Inheritance" was given to the public.

Mr. Galton came to be interested in finger prints in 1888, in connection with preparations for a lecture on personal identification and description. Having some misgivings concerning the adequacy of M. Bertillon's system of identification by measurement—because physical characters are not independent, but correlated—he cast about for other possible means, and undertook the investigation of finger prints.

Fortunately, Sir William Herschel who had actually used finger prints as a means of identification while commissioner in India learned of Mr. Galton's work and came to his aid with valuable prints and suggestions.

Identification by means of impressions of the papillary ridges of the thumbs has been so much exploited in fiction that a general explanation is unnecessary. This does not mean that an immense amount of hard work had not to be done on it by Mr. Galton before a British prison commission could adopt it. Besides the technique of taking really good impressions it was necessary to prove, not assume, that the patterns remain the same throughout life, that the variety of patterns is really very great, and that they admit of being classified or indexed. So when an individual set is submitted to an expert he can tell by reference to suitable records whether a similar set has been recorded.

These things were successfully accomplished and Mr. Galton's system of identification was adopted in Scotland Yard, and is now widely used throughout the world. His books on the subject are "Finger Prints," "Blurred Finger Prints" and "Finger Print Directory."

Space can not be taken for a review of the various anthropological questions which interested Mr. Galton, but a word must be said concerning anthropometric laboratories. Writing of Darwin's provisional theory of pangenesis in 1869, he said,

> The doctrine of pangenesis gives excellent materials for mathematical formulæ, the constants of which might be supplied through averages of facts, like those contained in my tables, if they were prepared for the purpose. My own data are too lax to go upon; the averages ought to refer to some simple physical characteristic, unmistakable in its quality, and not subject to the doubts which attend the appraisement of ability.

Realizing "the pressing necessity of obtaining a multitude of exact measurements relating to every measurable faculty of body or mind, for two generations at least, on which to theorize" he set about in many different ways to achieve this object. In 1882, he published a plea beginning "When shall we have anthropometric laboratories, where a man may from time to time get himself and his children weighed, measured and rightly photographed, and have each of their bodily faculties tested, by the best methods known to modern science?"

This plan was realized in 1884 when Mr. Galton established an anthropometric laboratory at the International Health Exhibition, London. Subsequently the laboratory was maintained in the Science Galleries of the South Kensington Museum for about six years.

It is impossible to summarize fitly the consequences of the establishment of these laboratories. Certainly they are not to be gauged by the tangible data which they yielded. The measurement of the various faculties required special apparatus, and our psychological laboratories and college gymnasia are greatly indebted to these pioneer institutions. From anthropometry in particular is a natural step to biometry in general.

With Francis Galton anthropometry was largely a means to an end—heredity. The titles of his major works on inheritance have already been given. Heredity in its turn was merely the scientific prerequisite for a humanitarian movement—eugenics. To this end it was with the few exceptions mentioned above concentrated upon man.

Among biologists one often hears misgivings expressed concerning studies of heredity based on man. "Obviously enough the laws of inheritance are the same for man as for other animals, or as for plants, but the material is not suitable for investigation," is the substance of frequent comments. In a degree this criticism is quite justified. Human pedigrees are collected with great difficulty, as compared with those of peas or fowls or mice. Even where the greatest caution is exercised, the opportunities for deception and concealment are very great, and individual pedigrees must be looked upon with the greatest caution.

These objections can not detract in the slightest degree from the credit due to Francis Galton. The work of an individual to be justly appraised must be judged in relation to the intellectual environment of his time, just as social or religious movements to be intelligible must be studied in their historical setting. In "Hereditary Genius" Mr. Galton records the results of an exploration of an entirely new field. In it he entered a *terra incognita* just as truly as when he turned his back upon the missionary outposts and his face towards the land of the Ovampo. Up to Galton's time men discussed heredity. He set about to measure its intensity. Even after much of his epoch-making work was published, prominent and otherwise well-informed men denied the existence of heredity in man. It is still urged by some that in the mental qualities nurture is of far greater importance than nature. So at the time when he struck out in a new direction in biology it was by no means obvious that heredity—to say nothing of the laws of inheritance—was common to man and the lower organisms. Our present belief that this is true is largely due to the labors of Galton and his school.

Again we must remember that even in "Hereditary Genius" he had definitely in view the possibility of race improvement. However unsuited human material may be for unravelling recondite laws of inheritance, it must be admitted that from its high sociological importance the problems of heredity and environmental influence must be investigated in the human species.

To discuss Galton's work on inheritance in greater detail at the present time would be a thankless task, for his immense service to the science of heredity and the great value of his methods for some problems of inheritance have been generally obscured by the enthusiasm over other means of attack. With a little time and a bit of Galtonian patience we shall perhaps arrive at a saner point of view than that now prevailing.

Galton's application of quantitative methods to the problems of human faculty and heredity is one of the forces which has gone into the formation of the biometric school of biologists. His influence in connection with this school is his greatest service to biology.

It may not be amiss to state here what the fundamental articles of faith of the biometrician are. They seem both simple and highly reasonable.

First, the biometrician requires that all observations shall be reduced, in so far as the material permits, to a quantitative basis. Gallileo's injunction to measure what is measurable and to render measurable what is not, must become the ideal of biologists, as it has long been of physicists, chemists and astronomers. When a sufficient number of biologists have made this the guiding principle of their work, the hoary and decrepit distinction between precise and biological sciences will pass away.

Second, the biometrician insists that generalizations be drawn only from adequately large series of observations. The living substance is so subject to as yet unknowable, or at least unmeasurable, influences that we dare not trust the "individual instance"; it is only upon a large number—and sometimes a very large number—of individual instances that conclusions of value may be drawn.

Third, the biometrician demands that the actual data, quantitative in quality and adequate in amount, shall be interpreted by sound logic. The most suitable logic, he believes, is that of the mathematician. This is agreed upon in theory by the most severely and variously disciplined minds. It has been rigorously tested in practise by the physicist and the astronomer, and the engineer joins with them in recommending it to the biologist and sociologist.

Surely these are simple articles of faith. Accompanied by the resolution to base theories on the entire array of observed facts pertinent to the problem in hand, instead of picking and choosing favorable evidence, and to fit theories to observation instead of gathering observations to fill out and stiffen up limp theories, they are, so far as I am aware, the whole creed of the working biometrician. He has no petrified hypotheses, and his theories are so plastic that they fit all but the minor irregularities of his data. He believes that industry in the description of natural phenomena by statistical constants is more important than assiduity in the imagination of explanations of them. He has no dogmas except unimpeachable quantitative data, sound logic, checked up arithmetic and cautious open-mindedness in interpretation.

Though simple in definition these ideals are attainable in practise only with the greatest care and exertion. After pointing out some of these difficulties in an essay on biometry written as an editorial for the first pages of *Biometrika,* Mr. Galton says:

> Consequently the new departure in science makes its appearance under conditions that are unfavorable to its speedy recognition, and those who labor in it must abide for some time in patience before they can receive much sympathy from the outside world. It is astonishing to witness how long a time may elapse before new ideas are correctly established in the popular mind, however simple they may be in themselves. The slowness with which Darwin's fundamental idea of natural selection became assimilated by scientists generally, is a striking example of the density of human wits.

The last ten years has shown the truth of these words. Those who have stood for biometry have had to do rather more than "abide for some time in patience," for lack of "sympathy from the outside" has been replaced by open hostility, often coupled with misrepresentation. The biological lump has been sodden and heavy, but the leaven is at last penetrating. A few years ago papers were not infrequently refused publication merely because they were biometric. Now every volume of the best biological journals bears more or less distinctly the impress of the methods associated with the names of Francis Galton and Karl Pearson.

Eugenics

A careful study of Mr. Galton's many short papers soon reverses any first impression of desultory ingenuity. Not only a connecting purpose but a practical end is often evident. Detailed illustration would be tedious. Military men have praised the "Art of Travel." His work at Kew Observatory and on the Metereological Council bear witness to this characteristic. The great success of finger print identification is perhaps a better example.

Nowhere is the bent for the practical to be more clearly seen than in his work on heredity. In the introductory chapter to "Hereditary Genius" of 1869 we read:

> I conclude that each generation has enormous power over the natural gifts of those that follow, and maintain that it is the duty we owe to humanity to investigate the range of that power, and to exercise it in a way that, without being unwise towards ourselves, shall be most advantageous to future inhabitants of the earth.

The subject had been discussed by him four years earlier in *Macmillan's Magazine*. In "Inquiries into Human Faculty" of 1883 we read:

> My general object has been to take note of the varied hereditary faculties of different men, and of the great differences in different families and races, to learn how far history may show the practicability of supplanting insufficient human stock by better strains, and to consider whether it might not be our duty to do so by such efforts as may be reasonable, thus exerting ourselves to further the ends of evolution more rapidly and with less distress than if events were left to their own course. The subject is, however, so entangled with collateral considerations that a straightforward step-by-step inquiry did not seem to be the most suitable course. I thought it safer to proceed like the surveyor of a new country, and endeavor to fix in the first instance as truly as I could the position of several points.

It must not be thought that Francis Galton's contribution to this branch of social science was merely the demonstration of the inheritance of both normal and abnormal bodily and mental traits. In "Human Faculty" of 1883 and in the preceding memoirs upon which it was based are many topics of great sociological importance: gregarious and slavish instincts, population, and racial migrations, early and late marriage, and marks for family merit.

One of these questions which Galton discussed a quarter of a century and more ago has attracted and is bound to attract increasingly the attention of sociologists. It is the question of the relative contribution of town and country families to future generations. "Urban selection" has often been discussed by anthropologists. If it be true that the physically fitter and psychically superior are drawn into the grind of the city, and if it be true that both physical and mental traits are inherited, then it becomes of paramount importance to learn whether the families in the city do their share towards filling the ranks of the oncoming generation. Under any system in which they do not, every large city is an open wound from which the best blood of the nation is being poured. As long ago as 1873, Galton attempted to measure the relative rate of supply of city and country families to the population of future generations.

The new science which purposes to gather and sift and coordinate data concerning factors which are of significance in determining the characteristics of races was christened eugenics by Mr. Galton as early as 1883. As defined in the publications of the laboratory which he has endowed "National eugenics is the study of agencies under social control, that may improve or impair the racial qualities of future generations, either physically or mentally."

Mr. Galton realized that nowhere is a scientific groundwork more essential than in eugenics. Compared with the dilettante in eugenics the quack in medicine is nothing in his power for harm. The danger reef lies in its attractions to the superficial and the hasty.

To the fundamental requisites of race improvement Francis Galton contributed in a two-fold manner. He gave much of the best vigor of his own long working lifetime and in his old age provided for its wider growth by endowing a university laboratory where the work might be continued along the lines which he began.

In the early sixties little more than superstition reigned concerning the influence of heredity and environment in man. Scientific data were almost unknown. Galton not only backed up his arguments by the best available evidence, but always dissatisfied with this and believing that "the basis of science is exact measurement" he gathered fresh quantitative data and taught others to do the same. Realizing that statistics "are the only tools by which an opening can be cut through the formidable thicket of difficulties that bars the path of those who pursue the science of man" he worked out methods for the more refined analysis of statistical data, out of which a whole modern science has grown.

If one turns from the work which he personally did to that of his laboratory it need only be said that if those laboratories to be patterned after this in other universities make good as it has done under the direction of his friend, Professor Pearson, a few years must show a marked advance in our knowledge of many of the basal problems of biology and sociology. From the Francis Galton Laboratory for National Eugenics have come, to mention only major topics, researches into the inheritance of the insane and tubercular diathesis, into the physique and intelligence of school children, into the influence of parental alcoholism on the physique and intelligence of the offspring, into the relative significance of constitution and infection in tuberculosis.

When a theory or a social propaganda wins its ways to public notice the historical critic seeks to trace it to its origin. Rarely is the credit of conception to be assigned to one man, although almost alone he may have compelled the world's attention.

The ideal of eugenics is no exception to this rule. The retrospectively inclined may look back as far as Plato. But the undeniable fact remains that it is Francis Galton who has forced thinking men to take these matters into consideration. The explanation is not far to seek. To-day men demand more than will-o'-the-wisp ideals. The dreamer who conceives and the engineer who executes are both essential and both to be honored, but for efficiency and progress their talents must be combined. Once the idealist, the prophet, the man religiously aflame passed through the street and swept the mob along with him. Now social advance is coming to depend more and more upon the results of cold scientific research.

Herein lies the success of Galton's movement. No accomplishment of recent times is of greater interest to scientific men, for the success which has been attained is due to a social and religious appeal made from a solid foundation of scientific facts. Opinions as to the direction of eugenic reform, or indeed as to the advisability of any immediate attempt at practical work, differ greatly but the widespread interest in its problems is an equally widespread admission that biology is to stand in the most vital relation to sociology, that science is to be the handmaiden of statecraft.

Hero worship must not blind the scientific biographer to the fact that in the doing of this Francis Galton was by no means single-handed. Those who preceded him in the fruitless suggestions of race improvement may be left out of account; those who labored with him can not. Indeed. I personally feel that in this work there is one name generally closely associated with his own which should take equal rank with his.

But Francis Galton must always rank as the pioneer—as the one who while the fighting was still hot around the "Origin of Species" and before the "Descent of Man" had yet been written had the insight to see and the courage to say not merely that man was to be included in the evolutionary chain but also that evolution has more than academic interest in its relation to man. He had the courage to argue that just as animals and plants are plastic in the hands of the breeder, so the physical strength and mental vigor of future generations may be moulded by a scientifically enlightened and morally quickened community.

The Man and His Methods

"The greatness of a man is shown in what he is, in what he does, and in what he sets a-doing."

It would be presumptuous for any one who had not the privilege of years of intimacy to write of Mr. Galton's character and personality. In paragraphs ranging from exploration through physical and biological sciences to eugenics an outline of what he did and what he set a-doing has been given. The two objects of this section are to state for the benefit of those who can not study his work in detail some of the characteristics of the investigator, and the cardinal features of his contributions to science. In essence, we have to determine what shall be understood by Galtonian.

A first characteristic was the ability to see essentially new problems or new methods of accomplishing things that needed doing. Some of his results—daily weather charts, anthropometric laboratories, human heredity—like those of Benjamin Franklin, had an obviousness which was cryptic to other eyes. Not only did he see problems but he had a peculiar faculty for searching out the significant thing and limiting his attention to it. Volumes have been written on palmistry, without the slightest practical outcome. Galton at once passed by the conspicuous wrinkles and folds of the palm, "which are no more significant . . . than the creases in old clothes" and concentrated upon the minute papillary ridges of the thumbs and fingers with the consequence of a workable system of finger print identification.

Correlated with this ability to look with discerning eyes on either side of the beaten trail and into the jungle was a peculiar independence of the herd. Most investigators are not surveyors merely, but in so far as specialty fences will allow, crowd with the gregariousness of cattle into the same field. Ecological surveys are in fashion to-day, centrifuging eggs holds the attention of the crowd to-morrow. Francis Galton's association with men was wide and intimate, he sought help from those of the most diverse accomplishments and always urged friendly cooperation and criticism, but as a conceiver of problems and methods his independence was all but complete. Perhaps this self reliance was gained in his early explorations. It is seen not merely in the formulation of problems. but in his freedom from the conventional paraphernalia and impedimenta of research. Every difficulty or emergency was an opportunity; the ready ingenuity was in direct proportion to difficulties opposed. Many uses for the sextant may be found in the literature, but it required a Galton to apply it for obtaining anthropometric measurements of Hottentot dignitaries where conventional methods might have been undiplomatic. Most travelers when ready to sail from a country would have swallowed their wrath at the loss of a favorite ox or would have retaliated blunderingly. By putting himself under the command of a Hottentot chief with his band, with the stipulation that a flogging was to be the only punishment of the Damara miscreants, Mr. Galton at once turned the annoying incident into a golden opportunity of studying the tactics of a savage raid.

Francis Galton by his studies of noteworthy men of science found that no special education other than self instruction is really necessary to the attainment of eminence. Access to superior tuition and laboratories have doubtless helped some to attain distinction who could not otherwise have done so, but they are by no means all important factors. "The facts that lie patent before the eyes of every medical man, engineer and the members of most professions, afford ample material for researches that would command the attention of the scientific world if viewed with intelligence and combined by a capable mind." The truth of these views he exemplified by his own life.

Writing of scientific eminence and scientific ability in 1869 Mr. Galton observed that some men become renowned because of a single striking discovery. Others of equally high natural gifts and energy in application have not this good fortune. Their results are valuable and remain, but the worker is forgotten. Still a third class "have shown their original powers by little more than a continuous flow of helpful suggestions and criticisms, which were individually of too little importance to be remembered in the history of science, but which in their aggregate, formed a notable aid towards progress." Notwithstanding all of the important fields in which his name should take honorable place, a writer in *Nature*, and one who is evidently qualified to write of the more personal side of Mr. Galton's life, has told us that his own strongest impetus to science was probably this continuous flow of helpful suggestions and criticisms, this personal inspiration, which he exercised over those with whom he came in contact.

Probably this is true. If one looks for the thing which was next in importance to the personal influence which he exerted, it will not be found in recorded observations but in scientific method. Were his share in the advancement of science to be measured by the quantity of bricks and mortar that we call concrete facts which he made available for others, his place would be an honorable one. But the question which seemed always uppermost in his mind was, how can the essential facts concerning this phenomenon be most easily and accurately obtained and interpreted? Everything he came in contact with presented a problem of method. He touched many fields, and so the problems in method which he set himself were numerous. The "Art of Travel," the standardization of instruments, the installation of self-recording meteorological batteries, the charting of meteorological data, the identification of criminals by finger prints, composite photography, methods and instruments for anthropometry, photographic records of pedigree stock, and finally the correlation coefficient, all attest his inventive genius and his eagerness to attain greater precision in every problem which he touched.

In the case of both Darwin and Galton the greatness of the man has stood in the way of his recognition. Sorting the work of either of them into the compartments of the specialty cabinet and comparing it there with that of others who have devoted themselves to one subject only, it seems meager in volume. Most men are interested in the contents of but one pigeon hole, or are incapable of considering more than a single compartment at a time. If we look under geography or geology, botany or zoology, anthropology, psychology or social science, we find the impress of Darwin and Galton there. But judged as specialists merely there may be some misgivings as to the claim to eminence of either of these grandsons of Erasmus Darwin. But now and then a man appears who chafes at the limits of a single cell, who feels that there should be additional compartments, or that partitions between established divisions should be broken and become nominal merely. He may even insist that the point of view or the method of research of all the specialists requires modification. Such a man may be so far in advance of his time that he is largely unappreciated by his contemporaries. This has been to some extent the case with Darwin and with Galton. Happily both lived to receive some parts of the tributes they deserved from their fellows.

How great is the debt of humanity to the Line of Darwin!

On the basis of an immense collection of the facts of natural history, Charles Darwin gave the world a theory which soon swept beyond the boundary lines of biology and by its clarification and unification of knowledge has been one of the powerful factors in modern life. Francis Galton was a leader in giving science methods which bring within the grip of mathematical analysis a wide range of biological, social and other natural phenomena hitherto regarded as outside the pale of exact science. Fifty years has made cultured men of all disciplines evolutionists, and Darwin's name is carved higher than that of any other who worked towards this goal, but after these fifty years we are still in deep ignorance concerning the processes by which evolution has taken place. This problem which has been the cloud by day and the pillar of fire by night in the onward march of biological research, awaits solution by the methods of Galton. Charles Darwin and the great men who came to his support sought to show that historically, in origin, man is not a separately favored being set in a garden of all living things to have dominion over them, but that his origin is a natural consequence of the struggle for existence, that step by step he has fought his way to the top of the evolutionary ladder, matching sinew with sinew and cunning with cunning.

Francis Galton and his school have proved that as applied to man this evolutionary process is not of class-room interest merely, but that its factors are of vital social importance to-day. A complex civilization may be likened to a cathedral of arches, every stone of which is under stress. The permanency of the civilization is limited by the physical and mental soundness of the component human stocks, just as the stability of the cathedral is limited by the texture of the stones which went into its building. Galton and his school have proved that in the determination of the character of the individual, nature is of greater significance than nurture—that the strength of the stone depends primarily upon the quarry from which it came, not upon the height to which it is polished nor upon the elegance of the colonade into which it is built. They have shown that in our strenuous modern life the statistician can point to some factors which tend to conserve and to others which tend to destroy the types of men which have made high civilization possible, and they have told us in ringing words that it is the duty of the man of science to apply the most rigorously exact methods to the investigation of all those factors which tend to improve or impair the racial qualities of generations yet unborn.

THE ORIGIN OF LUMINOUS METEOR TRAINS

By Dr. C. C. TROWBRIDGE

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THE nature of the luminous cloud occasionally left glowing in the wake of large meteors and called the "persistent" streak or train has long been regarded as a mystery by astronomers. Many of these trains have been observed which have remained visible to the naked eye for quite as long as fifteen or thirty minutes after the disappearance of the burning metorite itself. In numerous instances trains have lasted for more than one hour, floating in the cold upper atmosphere, a luminous mist-like cloud projected against the dark night sky.

Meteors are usually visible but for a few seconds in their rapid flight through the upper regions of the atmosphere at a velocity of from twenty to thirty or more miles a second. Their track is almost always marked by a bright streak of fast-fading luminosity which also disappears from view in a second or two. Occasionally, however, the streak remains for many minutes brightly glowing, continually expanding in size, and drifting with the moving atmosphere. This is the phenomenon which has been called the "persistent train."

Meteors which leave these trains are a very small proportion of the total number that are seen, yet authentic and definite facts concerning the trains have been recorded at various astronomical observatories in all parts of the world, hence the chief characteristics of this remarkable phenomenon are known.

A serious study of the subject has been made only recently, but it is now recognized as being of considerable importance because it teaches important facts concerning the upper atmosphere.[1] Most of the observations of meteor trains which from time to time have been made by different astronomers have been incidental in the course of the usual investigations of the heavens. Perhaps the best way to show the extraordinary features of the self-luminous meteor train is by drawings of a bright and long-enduring train carefully observed in England many years ago. The drawing marked *A* in the first illustration is a sketch made by one of the observers of the train as it appeared only a few seconds after the meteor nucleus had disappeared. This train, which was seen by many observers in the vicinity of both Sidmouth and Cardiff in England at the time of the great meteor shower of 1866, was formed

[1] A grant has been made by the National Academy of Sciences from the J. Lawrence Smith Fund to the author of the present article to enable him to extend his researches on meteor train phenomena.

by a meteor belonging to the swarm known as the Leonids, and appeared at first, as is always the case, a narrow glowing streak. The train soon after its appearance was sixteen to eighteen miles in length and at an altitude above the earth of fifty-six miles as determined by triangulation from Sidmouth and Cardiff, which are fifty miles apart. It appeared lance-like for a few moments and then was seen to be bending like a long floating ribbon, slowly curving about as shown in sketch *B*. The train also gradually expanded in size. The enlargement of these luminous clouds is unquestionably due to the diffusion of the particles of which they are composed. A careful study of the observations of a large number of trains has proved conclusively that the distortions, such as those shown in the illustrations, are due to the different wind currents that are in the atmosphere at great heights, even as far distant from the earth as sixty-five miles. It is also evident that these currents may vary both in direction and in velocity at different levels at one time, quite similar in fact to the drifts of the atmosphere in the cloud region near the surface of the earth.

Meteor trains have been observed more frequently during the periodic meteor showers than at other times, and apparently the meteors which have produced the greatest number of trains are the so called Leonids and Perseids. The former, it may be remembered, appear every year about November 14, but produce what is known as a meteoric shower every thirty-three or thirty-four years, the actual period being

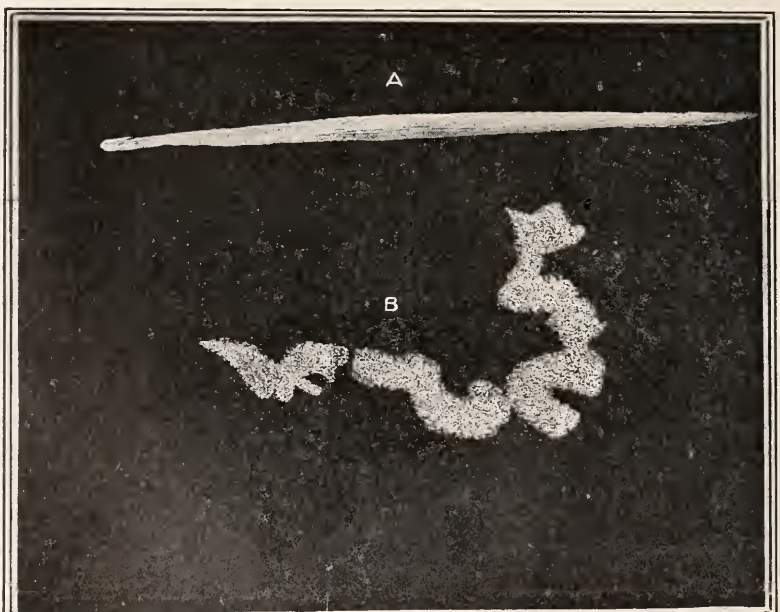


Fig. 1. Meteor Train seen at Sidmouth and Cardiff, England. Observed on November 14, 1866, at 1:08 a.m. Visible until 1:20 a.m.

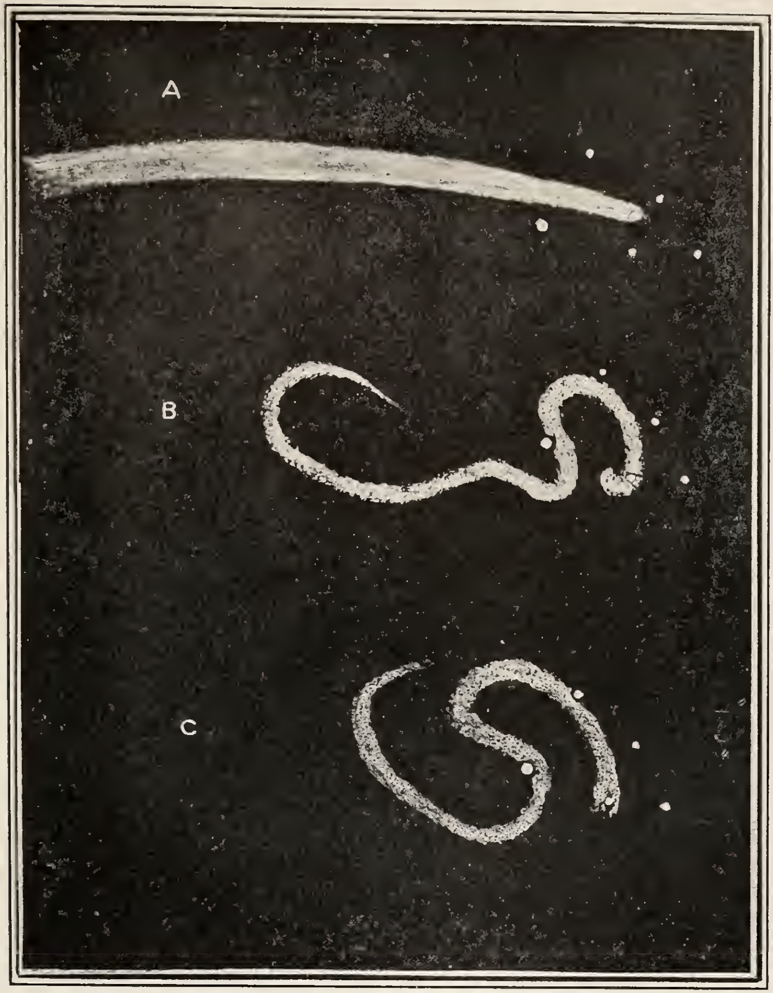


FIG. 2. METEOR TRAIN SEEN AT ABERDEEN OBSERVATORY, ENGLAND. Observed on November 14, 1866, described as a pale yellow band of light about half the diameter of the moon. *A* at 2:41 A.M., *B* at 2:43 A.M., *C* at 2:45 A.M. (The largest star in the cluster is Aldebaran.)

33¼ years. The showers of 1833 and 1866–7–8 produced many persistent trains. The Leonid shower in 1901 was very meagre as compared with those of 1833 and 1866, yet a number of persistent trains were observed at that time, which was the date of the last meeting of the earth and that part of the orbit of the Leonid meteor swarm where the meteoric masses are clustered most thickly.

The Perseid meteors appearing about the eleventh or twelfth of August are far more evenly distributed along in the track of their orbit than the Leonid meteors and hence there is no recurrent period when they are particularly abundant. Both the Leonids and Perseids are very

FIG. 3. METEOR TRAIN SEEN AT THE LEIDEN OBSERVATORY, HOLLAND. Observed on November 13, 1865. From a picture by the observer, Dr. Van Hennekelen. *A* as it appeared at 12:45 A.M., *B* at 1:13 A.M., *C* at 1:24 A.M.

rapid-moving meteors, and it may be that the formation of trains by them is partly due to their high velocity. Many trains have been observed which have been produced by meteors belonging to other swarms than those that radiate from the constellations Leo and Perseus, and thus it is possible for a persistent train, although an uncommon phenomenon, to occur on any night during the year.

FIG. 4. DOUBLE TRAINS OBSERVED AT THE PALISADES OBSERVATORY, N. Y. The trains are drawn as they appeared in a telescope; the double appearance is probably due to greater luminosity on the border of the train.

Among the astronomers who have made important observations of these trains are Mr. W. F. Denning, of Bristol, England, the acknowledged authority on meteors; the late Professor A. S. Herschel, who died about two years ago, the last of the three great Herschels; and a number of other well known astronomers, members of a committee especially organized by the British Astronomical Association for the observation and study of meteors. On the European continent Professors J. F. J. Schmidt and G. Von Niessl have contributed a great deal to the subject of meteoric astronomy. In the United States the late

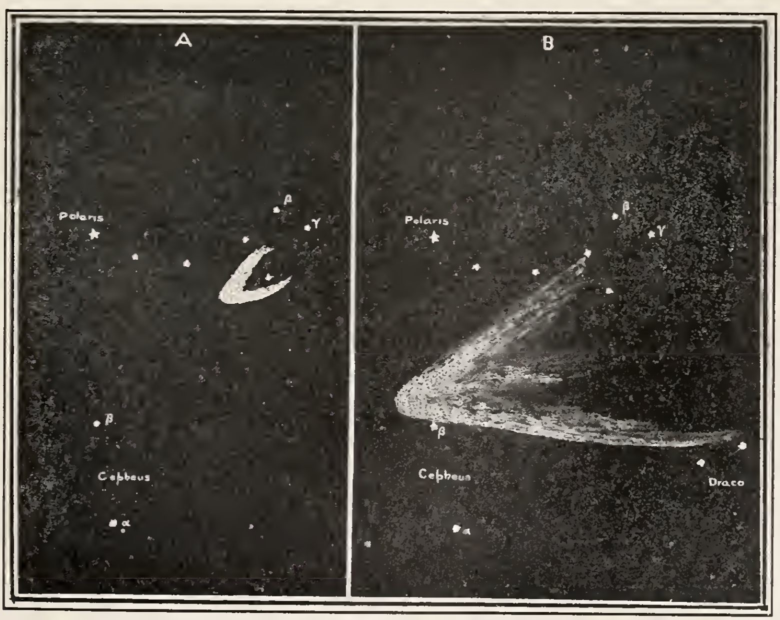


FIG. 5. COMET-LIKE TRAIN SEEN BY PROFESSOR E. E. BARNARD, NOVEMBER 14, 1901. *A* as it appeared at 3:10 A.M., *B* at 3:40 A.M. The drawings are copies of sketches sent to the author by the observer.

Professor H. A. Newton, of Yale University, was a constant observer of meteors and published many observations, and in recent years Professor E. E. Barnard, of the Yerkes Observatory, has added some important records of long-enduring trains.

Meteor trains are by no means as rare as might be supposed, and it is safe to predict that if a plan were organized for their observation on nights of the year when meteoric showers occur, many trains would be observed. This would be a source of new records which would throw more light on the subject. That trains would be seen if systematically looked for is demonstrated by the fact that nine different trains were seen by an observer in England during one night with the aid of a small telescope. The watch was kept at the time of an ordinary August Perseid shower.

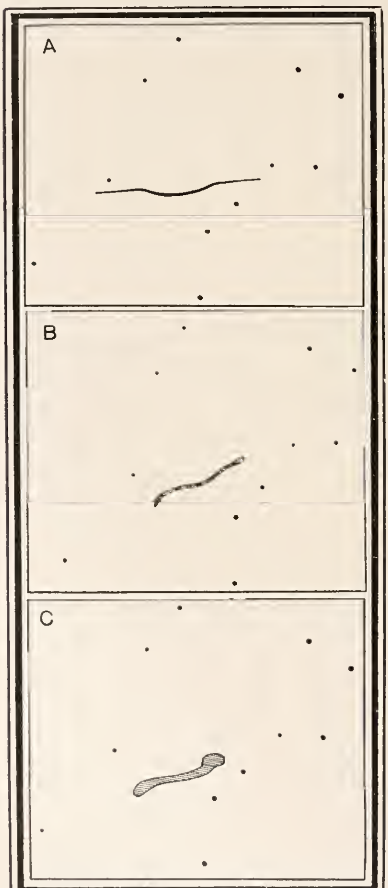


FIG. 6. GREENISH TRAIN OBSERVED AT JAMAICA PLAIN, MASS., NOVEMBER 14, 1901. Meteor fell at 5:09 A.M. *A* as the train appeared at 5:12 A.M., *B* at 5:17 A.M., *C* at 5:25 A.M.

Mr. Denning and Professor Barnard have pointed out that meteor trains visible to the naked eye for one or two minutes have been seen in the telescope for a quarter of an hour or more, and that by the use of a small low-power telescope they can be studied to greater advantage than by the naked eye alone. If the track of every bright meteor could be examined with a field glass, it is probable that many persistent trains would be observed which would be invisible to the naked eye. Moreover, Mr. Denning has shown that a great many meteors can be seen with a telescope which are otherwise invisible, and he also cites instances where he has detected persistent trains by the telescope.

In England a large number of trains were observed in the meteoric shower of November, 1866; two of these trains are shown in the illustrations. During that shower the long-enduring trains were so numerous that one meteor observer at Birmingham stated that the trains frequently were seen to be branched out from the radiant point, the constellation of

FIG. 7. DAYLIGHT TRAIN OF A DETONATING METEOR. Seen from the Lick Observatory, 7:30 P.M., July 26, 1896, visible for one half hour, from a drawing published by the observatory. The enlarged part of the train is the point where the explosion occurred, twenty-eight miles above the surface of the earth.

Leo, "like the spokes of a wheel, three or four at a time"! The radiant point is the region in the heavens from which meteors appear to emanate. Many trains have been observed on the European continent from time to time. One of these is shown in one of the illustrations. It was seen at Leiden in Holland on the night of November 13, 1865.

RECENT REMARKABLE TRAINS SEEN IN ENGLAND

A train which was observed all over the south of England during the evening of August 12, 1894, was formed by a meteor at 10:20 P.M.

and was very remarkable. Its drift across the country was noted by many observers. It was eight miles in length at first and drifted at the rate of 122 miles per hour at a height of 54 miles, and it was watched by observers in different cities for thirty minutes. It finally assumed a globular form, and at one time was calculated to be four miles in diameter, thus covering a space of at least ten or fifteen cubic miles!

A meteor leaving another long-enduring train appeared over the south of England at 7:30 P.M., February 22, 1909. Mr. W. F. Denning considers this meteor with its train the most remarkable one in modern times. The train gradually increased in brilliance and twisted about, assuming grotesque shapes. A part of it drifted to the northwest at a velocity of 80 miles per hour and remained plainly visible until 9:30 or 10 o'clock. Another portion of the phosphorescent cloud drifted at a very much greater speed; according to the calculations of Mr. Denning, the best authority on meteors, the rate of *300 miles per hour* was observed! This velocity is more than double that of any other drifting train hitherto observed, and indeed shows an extraordinary movement of the atmosphere. The train may have been illuminated for a time by sunlight on account of its appearance so early in the evening. This is the longest instance of visibility of a train seen at night. The record duration of a train illuminated by reflected light of the sun is that of the smoke train left by the meteor which exploded over Madrid, Spain, on the morning of February 10, 1896, and which was visible for five and one half hours as a reddish cloud.

Meteor Trains Observed in the United States in 1901

Professor E. E. Barnard, of the Yerkes Observatory, who has made a number of interesting observations of meteor trains reported two that he observed early on the morning of November 15, 1901. The first was formed by a brilliant meteor which radiated from the constellation Leo. This train was greenish-white in color, about 5° long, or a distance equal to ten times the diameter of the moon. It remained visible from 2:54 to 3:40 A.M. Another, which is shown by an illustration, was first seen at 3:10 A.M. and was conspicuous until 3:40 A.M., when it was obscured by clouds. Its color was greenish-white also. This train gradually expanded until it covered 20 or 25 degrees of the sky, forming two tails and appearing much in the likeness of a comet. Another train shown by three sketches made by the observer was seen by Mr. R. M. Dole, November 14, 1901, about 5:09 A.M. at Jamaica Plain, Mass. The large size of the train is made evident by comparison with the familiar stars of Ursa Major, "The Big Dipper," which appear in the drawing. The train was greenish in color, gradually turning to white. It was also seen at the observatory of Brown University, Providence, R. I. This cosmic cloud, according to an estimation which cannot be far wrong, was about two miles in thickness and fifteen miles in length. About the same time several persistent trains were seen at Dunmore, Northwest Territory, Canada, one of which remained visible twenty minutes, and several others were reported from the Mount Lowe Observatory, California, by Professor F. L. Larkin.

The Meteor Train Zone

It is evident that meteor trains that are observed at night occur at a very definite altitude, and furthermore various facts indicate that the formation of the train is due rather to the state of the earth's atmosphere where the train is formed than to the constitution, size or condition of the meteor itself. Also that the train is a glow phenomenon of the phosphorescent type and probably of electrical origin.

When meteors penetrate into the atmosphere of the earth they blaze forth at various heights, some even at as great an altitude as 100 miles, but the average height at which they appear has been found to be about 80 miles. The usual height at disappearance is about 40 miles. These altitudes are based on many observations. There is strong evidence in favor of the hypothesis that there is a certain *density* of the air which is favorable for the formation of the persistent train, because the altitude above the surface of the earth at which meteor trains occur when seen at night is usually confined to definite limits between forty-five and sixty-five miles, and the height which appears to be most favorable for longest visible duration is about fifty-five miles. Thirteen trains carefully observed at two or more stations, the altitudes of which have been determined by triangulation by well known astronomers, give a height of fifty-four miles as the mean altitude of the middle portions of the trains. The region where these self-luminous streaks of meteors occur extending from a little above sixty to a little below fifty miles altitude may well be called the *meteor train zone* of the atmosphere.

Trains of meteors which fall in daylight or twilight are not infrequently seen. They appear as thin smoke trains illuminated by the light of the sun, and according to triangulation observations which are possible only when the train is seen from two stations, they occur as low as twenty-five miles altitude, but seldom above forty miles. They are thus as a rule at a much lower altitude than the trains seen at night, which are usually, if not always, above forty-five miles. This fact would seem to indicate that in the upper levels of the atmosphere the glow does not mainly arise from light reflected from fine meteoric dust, but is a luminosity of the gas in the meteor's track.

The colors of the meteor trains show a good deal of variation according to the records of observations of different trains. The colors of trains observed at night include orange-yellow, emerald-green, bluish-green, silver and also white. In numerous cases green trains changed gradually to white, and in one instance from greenish to a "dull reddish." Apparently the color of many of the self-luminous trains observed are recorded as various shades of green, gradually changing to white as the train fades, and the remainder either bluish, silver or white. The residue of the meteorite is evidently a cloud composed of very finely divided smoke-like particles arising from the volatilization, combined with gases liberated at the same time. This cloud, if seen in daylight or illuminated in twilight by the sun, is usually red, yellow, or silver colored, much like the ordinary clouds as they appear just after sunset. The greenish luminosity of trains seen at night may be due to continued brush-like electrical discharges near the border of the train, but it is probable that it is the phosphorescence of the rarefied atmospheric air in or around the train. This hypothesis is suggested by the following experiments.

Experiments on Phosphorescent Gases in the Laboratory

An attempt has been made to reproduce the phenomenon of the meteor train in the laboratory. One of the interesting effects produced under certain conditions in a vacuum tube by electrical discharges is the phosphorescence of the particles of gas which still remain in the tube. This after-glow has been the subject of careful study. This type of luminescence is, of course, not the same as the oxidation of the element phosphorus, and is apparently different from, though very similar to, the phosphorescent light given out by insect larvæ, like the glow-worm, and insects such as the firefly. Phosphorescence is named for its likeness to the slow burning of phosphorus, but in the case of solids and gases, according to the best authorities, it is due to an unstable chemical condition, brought about by the excitation by light or by electrical discharges. The production of the phosphorescent light or after-glow is supposed to take place while the substance is returning to the former stable chemical state.

In one of the illustrations a photograph is shown of a vacuum tube containing a gas at low pressure, which is illuminated by gas phosphorescence. The gas was previously excited by an electrical discharge, but at the time the picture was taken all electrical discharges had been entirely cut off. Thus the photograph was taken by means of the phosphorescent light of the gas alone, no other light and no electrical discharge directly contributing to the formation of the picture. The gas which is glowing is atmospheric air with most of the oxygen extracted, and therefore is chiefly nitrogen. This gas phosphorescence has many points of resemblance to the meteor train, the chief of which are *first,* it is formed at a density of the air that, as near as can be determined, is the same as the computed density of the atmosphere at heights where meteor trains occur. *Second,* the comparison of observations of the spectra of meteor trains and those of gas phosphorescence apparently show that both are the *same kind* of spectra, although the location of

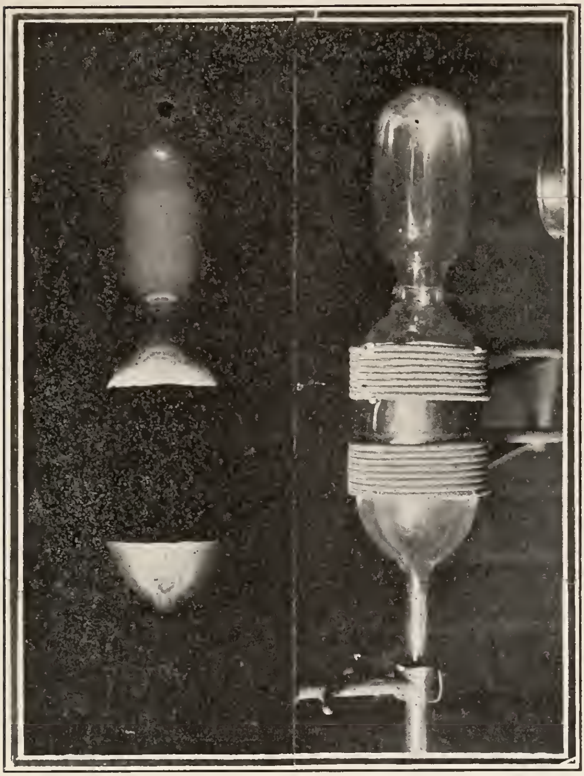


FIG. 8. VACUUM TUBE USED TO PRODUCE GAS PHOSPHORESCENCE AND PHOTOGRAPH OF GAS PHOSPHORESCENCE TAKEN BY ITS OWN LIGHT. Rapid oscillating electrical currents are sent through the coils about the vessel.

the spectrum lines of the former have not been determined. The general color of the phosphorescence in air is greenish-yellow which suggests the observed green color or meteor trains. *Third,* that recently by laboratory experiments the author of the present article has determined the law of the diminishing intensity of gas phosphorescence at successive intervals of time after the phosphorescence has been formed. The results of these experiments show that if the luminous meteor train is phosphorescent gas, the long duration of its visibility, often of half an hour, is readily explained from the law of the slow decaying or dying out of the luminosity shown by experiments on phosphorescent gases. This evidence and other facts point strongly to the hypothesis that the meteor train seen at night is due to phosphorescence of gas in the meteor's track.

How the Meteor Trains may be Formed

In the great Leonid meteor shower of November, 1866, and the showers following in the years 1867–68, it was noted at several observatories that the persistent luminous trains of meteors were not formed throughout the entire length of the visible path of the meteor. These observations are substantiated by the others more recently made. In Fig. 9, the tracks of seventeen trains are shown. The lengths of the paths with respect to *altitude* are drawn only. The paths of the meteors had different slants and hence differed in length very much more than shown in the drawing. The location of the *persistent train* is indicated with

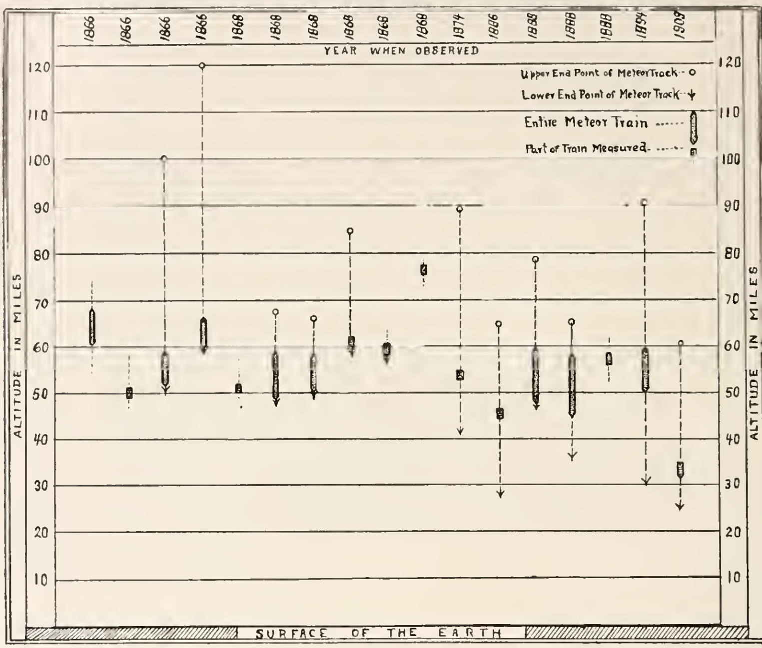


FIG. 9. CHART GIVING VERTICAL PROJECTIONS OF THE PATHS OF SEVENTEEN METEORS, showing the altitudes of the trains. In a number of cases the mean altitude of the train has been measured only.

respect to the length of the *entire track* or trail, and it is evident from the chart that the production of the long enduring glow has something to do with the altitude of the meteor above the earth. As already stated, the upper and lower limits of the zone in the atmosphere where the trains are formed appear to be usually about sixty and fifty miles respectively from the earth's surface. If the glow is considered to be a phosphorescence of the rarefied air in the meteor's track, the conclusion that must be drawn, based on laboratory experiments, is that the barometric pressure at these heights is not far from two-tenths of a millimeter of mercury, or, in the neighborhood of from one two-thousandth to one four-thousandth of the pressure at the surface of the earth. Any information relating to the density of the atmosphere at great altitudes would be of value, making this part of the research an important one.

It has been shown by the work of physicists, and particularly by the recent researches of Professor Richardson, of Princeton University, that when a body is very hot an immense number of negatively charged corpuscles or ions are given forth from the body. Air containing free ions becomes a conductor of electricity, hence we have in a meteor rushing through the atmosphere a condition extremely like a very long electrical discharge tube containing a gas at low pressure. The passage of the burning meteor through the atmosphere must form a column of highly ionized air thirty or forty miles in length. Moreover, at a certain altitude, corresponding to a pressure near two-tenths of a millimeter of mercury pressure, or about from one two-thousandth to one four-thousandth of one atmosphere pressure, the conditions are precisely right for the formation of phosphorescence in the meteor track. If at different levels in the upper atmosphere the air is at different electrical potentials, discharges must certainly occur in the meteor's track, and the burning meteoric mass thus may readily play the part of an incandescent electrode in a very long discharge tube, the column of ionized air being a ready conductor of electricity. When the meteor nucleus has been consumed, all that remains visible in the dark sky is the body of phosphorescent gas in the part of the track where the gas pressure conditions were correct for the formation of the persistent glow.

Under the above circumstances, it is not surprising that luminous effects are produced in the meteor train zone of the upper atmosphere where the density of the air is apparently the same as that at which luminous effects can be produced in vacuum tubes in the laboratory by even very weak electrical discharges.

It is not certain that electrical discharges takes place in the meteor track, but they may not even be essential for the formation of the phosphorescence. It has already been pointed out that the flight of a meteor through the atmosphere at the rate of twenty to thirty miles a second produces an exceedingly high temperature immediately about the meteorite, probably a matter of many thousands of degrees. The air thus heated and highly ionized by the burning meteorite, a condition which is sure to occur, may readily suffer chemical or physical changes in its composition which on gradually reverting to its original state gives out a long-enduring phosphorescent glow, just as is apparently the case in the formation of gas phosphorescence. Thus it is not unlikely that the production of the phosphorescent light of the meteor train is connected directly with the highly ionized state of the air and that this condition is produced by the outpouring from the intensely heated meteor of electrons, those electrically charged minute particles discovered by Sir J. J. Thomson which are supposed to play the important rôle in all electrical phenomena.

Design for the Eastern Facade of the American Museum of Natural History.

THE PROGRESS OF SCIENCE

THE EXTENSION OF THE AMERICAN MUSEUM OF NATURAL HISTORY

New York City has provided with wise foresight for the museum that it will need in the future by setting aside for the purpose the whole of Manhattan Square, extending from Central Park to Ninth Avenue and from Seventy-seventh Street to Eighty-first Street. The south side of the building now erected provides galleries of proportions not equalled by any municipal museum, and the completed structure will surpass any national museum. New York is growing more rapidly than London and will soon be the largest city in the world, even without counting the population of the New Jersey cities which form part of its social and intellectual life. The Public Library, which has just been formally opened, the Metropolitan Museum of Art, the Zoológical and Botanical Gardens, the buildings of Columbia University, New York University and the City College are planned in a manner fit for the greatest city in the history of the world. Its vast wealth can be put to no more worthy use than to give material expression to the dominant place that science, art and education should hold in the community.

The accompanying illustration, given here by the courtesy of the president of the museum, shows the design for the eastern façade of the great building, as sketched by the architects, Messrs. Trowbridge and Livingston. It has not been adopted by the trustees, but indicates the development that is proposed. The general style of the Romanesque architecture of the southern façade is somewhat modified in the direction of greater simplicity. The monumental building faces Central Park, and will become part of the park, being led up to by a driveway which might ultimately cross to the Metropolitan Museum.

A building of this magnitude will give ample space for the ideal development of a museum of natural history. As President Osborn has pointed out, there are three ways in which the collections should be exhibited—systematic, geographic and evolutionary. In one part of the museum, in accordance with the plan that is followed in most institutions, animals would be arranged for comparative study in accordance with their scientific relationships from whatever part of the world they may have been collected. A geographic sequence, as used by Alexander Agassiz in the Harvard Museum of Comparative Zoology, is equally instructive. The animal life of each region is shown together. The plan is especially well adapted to anthropological exhibits. Not less important than the distribution in space is the evolution in time, and an impressive series of connecting halls is planned for the fourth floor of the east side of the building, where the visitor can pass from the dawn of life through the ages of molluscs, of fishes, of amphibians, of reptiles and of mammals, until the age of man is reached.

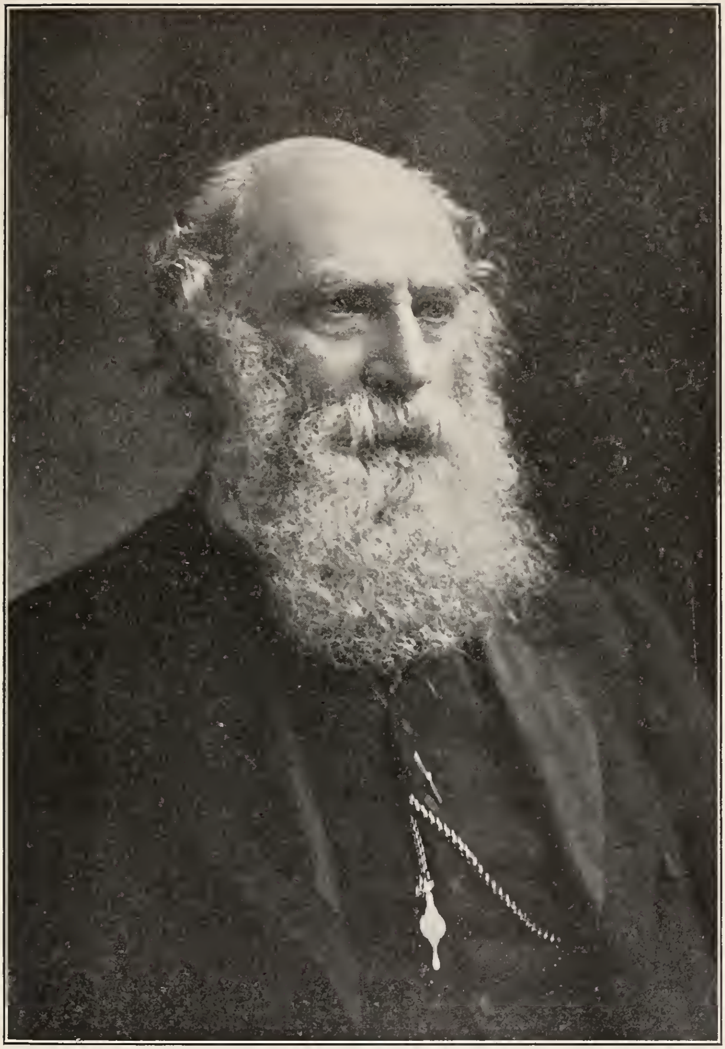
A great museum has two objects, neither of which can be subordinated to the other. It aims, on the one hand, to arrange exhibits which are instructive and interesting to the public and, on the other, to advance science by its expeditions and the study of its collections. Under the long and devoted presidency of Mr. Morris K. Jesup, with Dr. Hermon C. Bumpus as director during the later years, the American Museum accomplished much in both directions, but the main emphasis was placed on the educational side. It has led in artistic methods of mounting animals and exhibiting groups and has perhaps more than any other museum developed public lectures and relations with the schools of the city. Under President Henry F. Osborn, elected to the office in 1908, and under Dr. F. A. Lucas, elected director in May of this year, we may be sure that the popularization of the exhibits will be carried forward, while at the same time every effort will be made to draw to the museum officers of the highest scientific standing and to give them full opportunity to use its resources and collections for the advancement of science.

THE PROTECTION OF THE FUR SEALS

The fur seal treaty signed at Washington this month by representatives of the United States, Great Britain, Russia and Japan is the solution of a problem of much scientific and practical interest and at the same time an important extension of international arbitration. By the treaty the United States and Russia agree to give Canada and Japan thirty per cent. of the skins of the seals killed on the rookeries on condition that they will refrain from pelagic sealing. The powers agree to admit no skins the origin of which is unknown, and steps are to be taken to persuade other countries to prevent the use of their flags on the high seas by poachers. Provision is made for the patrol of the waters by representatives of the nations concerned. The agreement is to last for fifteen years and thereafter until it is denounced by one of the powers.

There is thus settled a problem that for many years has offended humanitarian sentiment and has even been in danger of causing international complications. In the year 1882 there were more than two million seals which went annually in the spring to the Pribilof and Commander Islands, where their young were born and reared. At about that time pelagic sealing, or the killing of seals on the high seas, came into vogue, the number of skins taken increasing from 10,000 in 1881 to 62,000 in 1894. It is said that for each skin taken, probably four seals are killed and lost. Eighty per cent. of the seals killed in this way are pregnant females, which at the same time are nursing their pups on shore, and the death of each sacrifices three lives. It is no wonder, consequently, that the whole number of seals has now been reduced to 150,000 and that they, like the sperm whale, are in danger of extinction. The seals on their breeding grounds can be treated like other domestic animals. The seal is polygamous and each male tries to obtain a harem of from ten to one hundred females. As there are an equal number of males, most of them can not succeed; they are isolated by the other males, and can be driven off like a flock of sheep and killed without injury to the herd, indeed, with benefit to it, as the fighting between the males and the incidental killing of females and young is thus prevented.

Since 1870 the United States government has received about ten million dollars by leasing the right to kill superfluous males on the Pribilof Islands—a larger sum than was paid for Alaska. In 1893 an agreement was made by which Canadians undertook not to engage in pelagic sealing within sixty miles of the Pribilof Islands, Russia and the United States having already forbidden this practise to their citizens. It was, however, found possible to engage in pelagic sealing at greater distances from the islands, and the greatest difficulty was caused by the Japanese, who were not a party to the agreement, engaging in pelagic sealing within three miles of the islands. In 1909 the Japanese pelagic fleet consisted of 23 vessels compared with five from Canada. Hence the need of the new treaty, which has been



DR. G. JOHNSTON STONEY, F.R.S.,
the eminent astrophysicist, born in Ireland in 1826, died in London on July 5, 1911.

so happily executed. A little while since, it is not likely that the United States would have paid Japan to refrain from killing animals which we regard as ours. The execution of such a treaty promises well for the possibility of similar efforts to preserve the sperm whales and for engaging in other enterprises of international conservation.

SCIENTIFIC ITEMS

We record with regret the death of Dr. Carl Beck, of St. Mark's Hospital, New York City; of Dr. I. W. Blackburn, pathologist at Washington, and of Sir Rupert Boyce, professor of pathology in the University of Liverpool.

Dr. Robert A. Harper, professor of botany in the University of Wisconsin, has been elected Torrey professor of botany at Columbia University.—Mr. Leonhard Stejneger has been appointed head curator of the department of biology in the U. S. National Museum to succeed Dr. F. W. True.

Dr. Abraham Jacobi, emeritus professor in Columbia University, was elected president of the American Medical Association, at the Los Angeles meeting.—Professor William G. Raymond, dean of the College of Applied Science at the State University of Iowa, has been elected president of the Society for the Promotion of Engineering Education.

The University of Göttingen has conferred the honorary degree of doctor of philosophy upon Professor Albert A. Michelson, head of the department of physics at the University of Chicago, and retiring president of the American Association for the Advancement of Science.—The George Washington University has conferred the honorary degree of doctor of medicine on Dr. L. O. Howard, chief of the Bureau of Entomology and permanent secretary of the American Association for the Advancement of Science, for "distinguished services to science in relation to preventive medicine."

The building named for Dr. Edward Williams Morley at the Western Reserve University and devoted to the departments of chemistry and geology, occupied this year for the first time, was opened for formal public inspection during commencement week. The building contains a tablet, bearing testimony to Dr. Morley's work in science, and to his thirty-seven years of active service in Western Reserve University.

THE POPULAR SCIENCE MONTHLY.

SEPTEMBER, 1911

THE BUREAU OF STANDARDS

By Professor HENRY S. CARHART

UNIVERSITY OF MICHIGAN

THE scientific bureaus of the government in Washington are conducting investigations on a scale and of a degree of merit not fully appreciated by the public because so little is known about them. The Imperial Institution known as the Reichsanstalt in Charlottenburg, a suburb of Berlin, has acquired international fame; and the National Physical Laboratory at Teddington in the environs of London is nearly as famous as a government institution of research.

In no way inferior to these is our own Bureau of Standards, situated out on the hills in Washington toward Chevy Chase. It has just completed its tenth year. Its activities in the interest of standards of measurement and of excellence entitle it to as high a position in popular favor as it already enjoys in the esteem of scientific workers and of those applying scientific data to practical ends.

The two prime functions of the bureau are to serve the government and the larger clientele of manufacturers and ultimate consumers. To which beneficiary precedence should be given is a question; happily whatever serves the one serves also the other.

The bureau is by law the custodian of all physical standards, and is authorized by the act creating it to exercise such functions as are necessary for their construction, comparison, maintenance and dissemination. In addition to these duties is the highly important one of defining standards of excellence for manufactured articles and materials of construction of which the departments of the government are large consumers.

The division of electricity has made its full quota of contributions to the fixing of standards of electrical measurement in comparison with similar institutions of other governments. In recognition of this fact,

A View of present Buildings.

one delegate each from the Physikalisch-Technische Reichsanstalt of Germany, the National Physical Laboratory of England, and the Laboratoire Central d'Electricité of France came to Washington in April, 1910, and in cooperation with representatives of the Bureau of Standards carried out an extended series of experiments on the three fundamental standards of resistance, current and electromotive force. As one result of this cooperative work an agreement has been reached with respect to the value to be assigned to the Weston normal cell; it has been accepted by the International Committee on Electrical Units and Standards, and is therefore universal. The difficulties in the way of the complete unification of international electrical standards have now practically all been resolved.

In the other field of defining and maintaining standards of excellence, this division has been no less successful. The incandescent lamp industry is a shining example. Before the establishment of the bureau, the navy department was under the necessity of seeking the services of the German Reichsanstalt for the purpose of standardizing lamps for use in the naval service. At that time the different departments of the government purchased lamps on independent contracts, while purchasing agents had no scientific means of justifying awards. Hence the intrusion of political influence with the object of securing contracts for friends or constituents. Criticism of such action was not justified so long as the government was without the means of defining and defending standards of excellence to which the articles purchased should conform.

It has happened in the past that awards have been held up by congressional influence, and the awards have been modified to include the product of small manufacturers, who claimed to make lamps in every way the equal of those made by the large manufacturers of wider experience and technical skill. Subsequent tests at the bureau showed that some of these added awards were filled by lamps which did not meet the requirements of the contract, and they were rejected.

At the present time the general supply committee awards contracts for all departments of the government and the Secretary of the Treasury signs them. This year the contracts for the list of articles for which the committee has made awards aggregate about nine million dollars. All departments are furnished with lamps purchased under uniform specifications, and tested the year round by the bureau. Moreover, the government now has the advantage of million rates instead of the higher prices attaching to contracts for smaller numbers.

The lamp contract of the government calls for about one per cent. of the incandescent lamps made in this country. The other 99 per cent. are sold to the general public. If the government took the best million made, while lamps of lower efficiency and shorter life were sold to the public, the government would be the gainer at the expense of other

THE ENGINEERING BUILDING.

consumers. But the fact is that the check held by means of the life and efficiency tests made at the bureau, and by the work of inspectors who visit lamp factories with bureau standards and instruments, has had the effect of gradually raising the quality of all lamps made; so that the consumer at large has profited equally with the government in the improvement of the lamp product. The bureau cooperates with the technical staff of the best manufacturers, large and small, and is in this way influential in raising the standard of excellence. Since the lamp trust fixes and maintains prices, the only advantage the government gains by competition is the competition in excellence. A consignment of 50,000 lamps has just been rejected because they fell ten per cent. below the guaranteed life.

The work of other divisions of the bureau, while not appealing perhaps so directly to popular interest, are of no less value to the public weal. For example, the bureau is the legal custodian of the international primary standards of length and mass in the form of the national prototype meter and kilogram, by which the yard and the pound are respectively defined. From these and by methods and instruments of the highest precision our customary commercial and scientific standards are derived. In fact the integrity of our gold and silver coinage can be maintained only by occasional refined checks against the ultimate standard of mass in the vaults of the bureau. The prototype standards are composed of incorrodible metals in alloy; no standard made of brass, for example, could be trusted to withstand the effect of oxidation during a long period of years, though happily a recent test at the bureau of the celebrated brass "troy pound of the mint" shows that it has not changed in the 83 years since it was received from England by more than 0.005 grain.

The Coast and Geodetic Survey is engaged in extending its measurements across the continent by means of triangulation. Formerly the survey had only about twelve base lines, each from five to ten miles in length, extending 3,000 miles from the Atlantic to the Pacific. These base lines had been measured with the greatest precision and at night to avoid temperature changes. The department is at present engaged in filling in intermediate base lines, which can now be measured readily by means of modern steel and "invar" tapes to one part in a million. Moreover, the work can be done daytimes and with steel tapes under known tension. The bureau compares these tapes, under the same tension and at the temperature of melting ice, with the primary standard of length, the national prototype meter. Thus it comes to pass that our continental surveys from Maine to California, and even to Alaska, are on the same basis of measurement as those made in other parts of the civilized world.

The bureau is charged with the duty of furnishing to the several states commercial standards of weights and measures in common use. It offers its services free to the state authorities and invites to a con-

A Corner in an Electrical Laboratory.

ference every year state and city sealers of weights and measures for the purpose of discussing the best methods of securing the use of legal measures of all sorts, and the prevention of frauds by the commercial use of fraudulent weights. The frauds committed against the government by the sugar refiners were nothing in comparison with those perpetrated on the people by short weight in small commercial transactions.

The bureau has in the field a force of inspectors, cooperating with the state authorities in the detection of fraudulent weights and of short liquid and dry measures. Some of these are used innocently, but many show unmistakable fraudulent intent. The fifth annual conference on weights and measures adopted a resolution favoring legislation requiring that all containers be plainly marked to indicate their net content; also that authority be given to the Bureau of Standards by congress to pass on types of weighing and measuring devices used in trade.

The division of heat has had a particularly arduous task to perform. In contrast to the certainty and permanency of standards of length and mass, and of electrical quantities, there have been great discrepancies in temperature scales and the thermal constants depending on them. The standards used by different makers of thermometers were not in agreement with one another, nor did they agree with the accepted gas scale. There were marked differences even between the usual limits of freezing and boiling, or 0° and 100° C. When the work on thermometry was undertaken, a large per cent. of American-made thermometers for temperatures as high as 400° to 500° C. were subject to changes of 30° or 40° when exposed to the high temperatures they were designed to measure. Further, the average clinical thermometers, used so extensively by physicians, were subject to errors exceeding the limit of tolerance. At least 30 to 40 per cent. of the clinical thermometers on the market at the beginning of the work would have failed to pass the requisite test; to-day only about five per cent. fail. The bureau now tests many thousands of them annually. So great has been the improvement in American-made thermometers that the German makers are complaining more and more of the loss of American trade in thermometers; and some familiar types of mercury-in-glass thermometers are no longer classed as instruments of precision.

Not only has the bureau authoritatively fixed the scale ranging from 0° to 500° C., but it has met a demand for the accurate measurement of very high temperatures by investigating optical and radiation pyrometers, in which the temperature of an incandescent body is measured by the amount of light or heat emitted. The intensity of red light emitted by a body at 1500° C. is over 130 times as great as at 1000° C.; and at 2000° C. it is more than 2100 times as great. Hence the possibility of a rough estimate of the temperature of hot bodies in the arts by an experienced eye. The temperature scale of the bureau is now reproducible to about 1° at 1000° C. and to about 10° at 2000° C.

It should not be supposed that the constant efforts for higher accuracy are made to satisfy the dreams of the pure scientist; they are demanded by the requirements of technical tests and commercial processes. The character of some products is materially affected by a variation of 20° in the very high temperatures employed in their manufacture, and an accuracy of about 10° is required. To meet this demand there must be the exercise of many precautions and the elimination of many sources of error.

The importance of great accuracy is well illustrated by a test which the bureau was called on to make in a dispute between a purchaser and a seller of coal, in a case where the contract was based on the heat value of the coal, with a penalty clause for any deficiency in the heat value, and a premium for any excess above the stipulated one. A difference of about 0.05° was found between the thermometers used by the two parties. While this difference was small, it was sufficient to bring the parties into agreement, and to make a difference of some $25,000 a year in the money paid for the coal.

The division of optics has been engaged in many investigations of moment, but none of more practical value than the improvements in the application of polarized light to the testing of sugar solutions by means of the polariscope. Plane polarized light differs from common light in having all its vibrations reduced to a single plane. The optical property of a sugar solution utilized to determine the amount of sugar present is its property of rotating the plane of polarization when the polarized light passes through it. The degree of rotation determines the per cent. of sugar present.

The bureau is able to make immediate application of its research work in this field, thus directing public attention to the results attained. As a result of the polariscopic tests of imported sugars at the bureau, the differences in the findings at the five principal sugar ports of entry have been reduced to 0.2 per cent. The importance of this work grows out of the fact that it increases the accuracy of the tests made on dutiable sugars and rigidly defines the scientific basis on which the revenues from them are collected.

The division of chemistry is in a large way auxiliary to all other divisions and cooperates with them in giving such service as chemistry alone can offer. It has been indispensable in the work of the division of electricity; it has prepared materials in the purest form for setting up Weston normal cells as standards of electromotive force, and for use in the silver voltameter for the international unit of electric current.

Much of the labor in testing supplies offered by the bidders under the new system of purchase by the General Supply Committee devolves on this division. The analyses of writing and printing inks, paper, and mucilage alone amount to an annual total of about 2,000 samples. These chemical analyses and conjoint physical tests furnish a scientific basis for more definite specifications for future purchases.

A demand has developed for certified samples of iron and steel of definite composition; also for samples of sugar of the highest purity. Many hundreds of these are sent out annually. They are highly impor-

THE POWER HOUSE AND LOW TEMPERATURE BUILDING.

tant to encourage the growing tendency to apply pure science to commercial processes in place of haphazard traditional methods.

The engineering section of the bureau is one of the later ones established. It has already much more than justified itself. In addition to the work in Washington, designed to secure fundamental data for engineers, it carries on investigations at Pittsburgh in the building turned over by the Geological Survey by direction of the last congress. The work in Pittsburgh under the old organization formed a part of the technological division of the survey.

The engineering division is performing an important service for the government in testing all cement made by the Atlas Cement Company for the Panama Canal. The company furnishes cement at the rate of 6,000 barrels a day. Inspectors are stationed at the works, and the bureau maintains there a well-equipped laboratory.

The testing of all paper purchased for the Government Printing Office falls within this division, in cooperation with the division of chemistry. Formerly bids were received on specifications, the lowest bid was accepted, and then the successful bidder proceeded to furnish the cheapest paper he could get accepted without further regard to the specifications. The results were that the best paper manufacturers refused to bid because they could not afford to sacrifice their reputation, and the government was defrauded. On one occasion the award for paper for the *Bulletin* of the bureau was made on specifications calling for paper of definite weight and half rags. When the paper had been made and submitted to the Printing Office, the analysis of the bureau showed that it contained no rags whatever, but only wood pulp.

At present print papers are bought on rigid specifications, and samples of all shipments are analyzed at the bureau. The fraud perpetrated on the government in the matter of print paper of all grades has now been eliminated.

Printing inks are purchased at present in the same manner, and the assistance of the bureau has saved the government in this particular item enough to cover about half the cost of the inks. The same system has stopped the graft by commissions once practised in the Bureau of Engraving and Printing by a trusted foreman. The price was very high on account of the generous commission allowed the foreman. Preferences for a particular make of ink or other commodity must now be supported by something more than the dictum of an old employee.

The engineering division does not confine its activities to the direct service of the government. Its aim is also to furnish scientific and physical data which lie at the foundation of engineering practise and design. It is now engaged in the actual measurement of the stresses producing compressions and elongations in the steel members of bridges and other structures after erection, as compared with those calculated by the designers. The results of such a comparison should be of eminent service to engineers and makers of structural steel, as well as to the government in the design and construction of its battleships. The largest testing machine, now in process of erection at the bureau at a cost of $150,000, is to be a marvel of precision. It will apply a maximum force of compression of 2,300,000 pounds, and will measure it with an accuracy of two pounds.

This brief survey of the activities of the Bureau of Standards is

Representatives of the National Standardizing Laboratories of Germany, England, France and America at the Bureau.

necessarily incomplete. It touches the high spots and refers only to matters likely to be of most popular interest. The work is progressing in all divisions with a vigor and comprehensiveness that promise even better results for the near future. The last congress made an appropriation of $200,000 for the erection of an additional building for the exclusive use of the division of electricity. The pay roll of the bureau includes about 280 names, and after July first it will be increased to something over 300. The additional assistants will enable several divisions to push forward work of great practical significance.

It would be an injustice not to say that the success of the bureau has been due in no small degree to the continuous service in their respective positions of Dr. S. W. Stratton as director, Dr. Edward B. Rosa as chief physicist, and Mr. L. A. Fisher and Mr. Charles W. Waidner as associate physicists at the head, respectively, of the divisions of weights and measures and of heat.

The scientific conclusions and data secured are published in a series of bulletins, which have now reached the seventh volume and which bear witness to the activity of this branch of the public service. In addition to the bulletins, circulars on important practical problems are issued from time to time; these are sent freely to persons and firms likely to need them in their professional practise or in manufacture. It is a matter worthy of the highest praise that party politics has never had any place whatever in the support or work of the Bureau of Standards.

ON THE HISTORY OF INTERNAL MEDICINE[1]

By JOHN BENJAMIN NICHOLS, M.D.

WASHINGTON, D. C.

As a subject of general rather than of technical interest appropriate to this occasion, I propose to present a brief historical survey and some considerations relating to the development of internal medicine.

One of the primitive tendencies of human nature is the development and employment of procedures aiming at the relief of personal ailments and injuries. It is probable that all peoples have to a greater or less extent developed something in the way of therapeutic practises. In primitive stages of culture some agents of efficiency may have come into domestic and popular use; but the chief development of medicine in primitive societies has been in association with religious cults or superstitious observances. Originally medical practise was mainly a function of the priesthood. Even under such conditions the powerful force of psychotherapy must have been brought into action so as to be of benefit to distressed humanity.

Ancient writings have preserved to us some account of the therapeutic methods in vogue in the earliest historic civilizations, such as the Egyptian, Jewish, Babylonian, Assyrian, Indian, Chinese, etc.; among these medicine was chiefly practised by the priests. It was among the Greeks, however, and especially by Hippocrates and his associates 2,300 years ago, that the foundations were laid from which through a continuous line of existence and evolution can be traced the development of civilized medicine to its present state. Probably from the Egyptians and other antecedent and neighboring nations were derived some contributions to Greek medicine, but the derivation is not now clearly traceable, and practically the school of Hippocrates stands as the originator of the present era of medicine. Since his time the development of internal medicine has been intimately involved in four great epochs or movements of civilization and thought, so that its history is divisible into the following corresponding grand epochs:

1. Greek (also Roman and Byzantine) medicine; from before 500 B.C. to the fall of the Roman Empire,— A.D. 476 (Rome), 640 (Alexandria), 1453 (Byzantium).

2. Arabian medicine; about 750 to 1200 A. D.

[1] Presidential address before the George Washington University Medical Society, May 20, 1911.

3. Medieval medicine; about 500 to 1825. Monastic medicine; 500 to 1200. Scholastic medicine; 1200 to 1600. Systematic medicine; 1600–1825.

4. Modern medicine; since about 1825.

Greek Medicine.—The early medicine of the Greeks, as of other peoples, had mythologic and theologic characteristics. The god of medicine among them was Asclepios, or (Latinized) Æsculapius, who perhaps was a real physician flourishing prior to 1000 B.C. The temples devoted to his cult, called Asclepieia, were located in salubrious situations, or at mineral springs; invalids resorted to these institutions in large numbers, and were ministered to by the physician-priests. Famous Asclepieia were situated at Cnidos, Cos, Epidaurus, Pergamus, Tricca, Mycenæ and Sicyon. Gradually there developed in connection with these institutions associations or guilds of physicians called Asclepiadæ, who devoted their entire time to medical practise and instruction and had no priestly functions. The separation and differentiation of the functions of the physicians from the priesthood marked an important step in the evolution of medicine, as it left medicine and the medical profession free to develop along independent lines, entirely dissociated from priestcraft. These associations of Asclepiadæ formed schools for medical instruction and were centers of medical thought and influence. Such schools or guilds were located in Cnidos (Asia Minor), Cos (one of the Ægæan Islands), Rhodes, Cyrene (north Africa), and Crotona (Italy). The two most noted were those of Cnidos and Cos. Literary remains from the school of Cnidos have probably survived in the Hippocratic writings; while the school of Cos, which was flourishing prior to 500 B.C., produced the illustrious Hippocrates.

Hippocrates lived from about 460 to 377 B.C., a period when Greek culture and civilization were at their zenith. Originally trained in the temple and school of Cos, he traveled extensively and resided and practised in various places. His fame is derived from his writings. Of the works attributed to him, about sixty in number, only some ten to seventeen are regarded by the critics as being indisputably his production, the rest having been written by others before and afterward.

The Hippocratic writings constitute a systematic and comprehensive presentation of medical and surgical observations, doctrines and practise. Especial attention was given to prognosis, dietetics and meteorological conditions as causes of disease; and the beginning was presented of the humoral pathology, which for ages dominated medicine. All this mass of knowledge and doctrine could hardly have been discovered or elaborated by Hippocrates himself, but was probably mainly the accumulated knowledge of his predecessors first placed in literary form by him, and illuminated by his own keen observation, criticism and individuality.

There is little in the writings of Hippocrates of direct value to us to-day; yet while crude, imperfect, and visionary, they were of profound importance in the development of medicine. They constitute the first systematic literary presentation of pure medical science and art, aside from sacerdotal systems. They were, for the time, a very creditable beginning toward the development of rational medicine; and had progress in the subsequent ages been as substantial as that in the brief time prior to Hippocrates, the history of internal medicine for the ensuing two thousand years would not have been one of stagnation and inefficiency. Hippocrates showed himself to be a keen observer of clinical phenomena, a master clinician, and the part of his work of permanent value was the accumulation of clinical facts by observation, or the empirical method of developing medical knowledge which time has shown to be the only efficient method. Hippocrates displayed the noblest conception of the medical vocation, and in this, with his method of developing clinical knowledge, he set a standard and example for all time.

The doctrines of Hippocrates did not immediately gain general acceptance; soon after his death they nearly fell into oblivion, but six centuries later they were revived and given a vogue by Galen and then attained a dominant influence which they continued to exercise until the dawn of the modern era. During the interval between Hippocrates and Galen (B.C. 400 to 200 A.D.) a number of medical systems developed and continued in force for varying periods. The principal of these systems were:

1. The Dogmatic School.—This, based on the theories of Plato (B.C. 427–347), was developed by the immediate successors of Hippocrates, but it survived for only a few decades. The doctrines of this sect were highly speculative, and the humoral pathology was a fundamental tenet.

2. The school or following of Herophilus, originally located in Alexandria, flourished about B.C. 290 to A.D. 100. Herophilus, its founder, lived about 335–280 B.C., was one of the earliest anatomical investigators, and in part followed Hippocrates.

3. The school of Erasistratus, a famous contemporary and rival of Herophilus, also of Alexandria. His following flourished about B.C. 280 to A.D. 200.

4. The Empirical School, which existed about B.C. 280 to A.D. 117, was based on the skeptical philosophy of Pyrrho (B.C. 376–288). It rejected hypothetical speculations on the underlying causes and nature of phenomena, and recognized as valid only such knowledge as was derived from observation and experience. This school, therefore, had the only successful method of developing knowledge, identical with the modern inductive and scientific method, but it was not acceptable to the ancient and medieval habits of thought.

5. The Methodist School was founded by Asclepiades (B.C. 128–56) and his pupil Themison. It was an application of the atomic philosophy of Leucippus and Democritus to medicine, holding that vital and morbid phenomena depended on the movements of atoms or particles through pores in the body. The methodist doctrines exerted a strong influence on medical thought for many centuries.

6. The Pneumatic System, about A.D. 70 to 160, was founded and chiefly represented by Athenæus of Attalia. Its pathology was based on an aerial or gaseous principle.

7. The Eclectics, who date from about 50 A.D., had no common or distinctive views, but individually developed widely differing systems. Among them were included some of the most eminent physicians of antiquity. Aretæus (about 30–90 A.D.) was one of the earliest and most distinguished. Two other eminent writers of about that period deserve mention, namely, Celsus (about 30 B.C. to 50 A.D.), a brilliant encyclopedic writer on medicine, and Dioscorides (40–90 A.D.), who wrote a treatise on materia medica which remained an authority almost to modern times.

The greatest of the Eclectics was Claudius Galen (about 131–206 A.D.), of Pergamus and Rome. He received an exhaustive education at Pergamus (in Asia Minor), and other educational centers, and especially at Alexandria. He was a most prolific writer, not only on medicine but on other subjects, his works numbering between three and four hundred. He made important and extensive original contributions on anatomy and pharmacology. In internal medicine his system to a considerable extent was a revival and amplification of the doctrines of Hippocrates. So powerful was his influence that for nearly fifteen centuries Hippocrates and Galen continued the main authorities and basis of medicine.

From about the second century B.C. Greece and the entire civilized world of that time had come under Roman dominion; but though the political administration was Roman the culture and civilization of the Roman Empire was of Greek origin and character. The early medicine of the Romans was very crude, consisting mainly of superstitious observances under the auspices of soothsayers and priests; and there was no important Roman addition to medical knowledge. Later, Greek medicine and practitioners were introduced among the Romans, and prevailed until the fall of the Empire. Asclepiades (B.C. 128–56), the founder of the methodist school, was one of the main agents in establishing Greek medicine in Rome. Alexandria was for centuries the greatest center and headquarters of learning and education of the ancient world; it contained a vast library and produced important systems of philosophy and medicine.

Subsequent to Galen medicine in the Roman Empire came to a standstill or suffered decline, and the few writers who attained any note were little more than compilers of and commentators on the more ancient authorities. Greco-Roman medicine came to an end in the west with the fall of Rome in 476 A.D., while the capture of Alexandria and burning of its great library by the Arabians about 640 ended the intellectual influence of that city. In the Eastern or Byzantine Empire, Greek medicine continued for a longer time, overlapping the Arabian period. Among the important writers or compilers of this later (post-Galenic) period may be mentioned Oribasius (A.D. 326–403), Alexander of Tralles (525–605), and Paul of Ægina or Paulus Æginæta (about 600). Ultimately Greco-Byzantine medicine declined with the decay of the Eastern Empire, its last distinguished exponent being John Actuarius (died 1283); and the last remnant of the Roman Empire and of direct Greek influence came to an end with the capture of Constantinople by the Turks in 1453.

Arabian Medicine.—Soon after the Roman Empire fell, another people, the obscure Arabian tribes, energized by the religion founded by Mahomet, burst forth and established a vast dominion under whose fostering care enlightenment and learning were carried along during the centuries while Europe floundered in darkness and chaos. The Moslem era is dated from the Hegira, or flight of Mahomet from Mecca, in 622. Within a few years from this the Arabians, organized and inspired by the new religion, overran and conquered western Asia, northern Africa, and Spain, and over that wide territory established a dominion that lasted for six centuries. This dominion soon broke up into two independent divisions or sovereignties, the eastern Caliphate, embracing the Asiatic territories, and the western Caliphate, in Spain. About 750 two enlightened dynasties were founded, one in the east with its capital at Bagdad, the other in Spain with its capital at Cordova, both of which encouraged and developed culture and education to a high plane. The Moorish dominion in Spain was broken in 1212, and the eastern Caliphate was overthrown by the Mongols in 1258. The Arabian period of culture therefore covered the years from about 750 to 1200.

During this period the Arabian scholars collected and translated the learning of the Greeks, Persians and Indians, and cultivated the arts and sciences, especially architecture, philosophy, mathematics, astronomy, geography, alchemy and medicine. In some branches they made notable advances, as in mathematics; but in the main their chief service was more in conserving the learning of the past than in creating new knowledge. Important schools, libraries and hospitals were established, especially at Bagdad and Cordova, but also at Damascus, Samarcand, Bokhara, Seville, Toledo, Granada and numerous other cities.

In medicine the Arabians displayed great interest and proficiency, and they produced a large number of writers and authorities on this subject. These were mainly translators, compilers and commentators of the Greek medical writings, so that their chief service to medicine was the preservation and transmission to succeeding ages of Greek medical lore; although they did make some material contributions in the differentiation of eruptive fevers and the introduction of certain drugs. The Arabians adhered quite closely to the authority of Galen. Of the large number of known Arabian medical writers three stand preeminent, Rhazes (850–932) and Avicenna (980–1037) of Bagdad, and Averroes (1126–1198) of Cordova.

Medieval Medicine.—During the four or five centuries following the fall of Rome (476), known in history as the Dark Ages, medicine in Europe shared in the general intellectual torpor of the period. No eminent medical writer or practitioner appears in the annals of christendom during this time. It is probable that the traditions and practise of Greek medicine gradually declined and the practitioners of the art became greatly degraded from their former standing. Ultimately medical and surgical practise came largely into the hands of members of religious orders (monastic medicine).

The revival of medical science in medieval Europe dates from the development of the famous secular medical school and university of Salerno in Italy, the first of the great European universities. Salerno was a salubrious town and health resort located on the seacoast a short distance southeast of Naples. The origin of the medical school at Salerno is obscure; it may have been founded by Charlemagne, and it is also supposed to have had early relations with the famous Benedictine monastery of Monte Cassino, north of Naples, which was itself a seat of a hospital and monastic medical school. The propinquity of Salerno to Sicily, which for a time was under Saracen dominion, made the Arabian influence accessible. The school of Salerno was in operation by the middle of the ninth century (846), Greek (Hippocratic) medicine being cultivated. The most famous and influential of its earlier teachers was Constantinus Africanus (1018–1087) of Carthage, who had traveled and studied extensively, and is credited with having introduced Arabian learning into Europe; he later became a monk at Monte Cassino. The school at Salerno was at the height of its fame and influence, which extended all over Europe, during the eleventh and twelfth centuries, but after the establishment of the great European universities in the thirteenth century it lost its preeminence and rapidly declined, though it continued in nominal existence until the nineteenth century.

The second European medical school was that of Montpellier, near the Mediterranean coast of France. The date of its establishment is unknown, but it was in operation in 1137; it attained the highest repute as a medical school, and has ever since continued in a flourishing and influential existence. There was a celebrated hospital at Montpellier, taking advantage of the salubrious climate of the Riviera, and its proximity to Spain made the Moorish learning accessible.

The thirteenth century, in which occurred the downfall of Arabian empire and culture, saw in Europe a great intellectual revival. Many great universities were founded within a few decades from the year 1200, such as those of Bologna, Padua, Naples and Rome in Italy, Paris, Orleans and Toulouse in France, Oxford and Cambridge in England, and others. The medical instruction given in these institutions, and in others founded later, has ever since been the fountain of medical knowledge for the world and conferred upon the medical profession the stamp of learning and repute.

During the middle ages medicine shared in the intellectual characteristics of the period. It was an age of dogmatism and intellectual narrowness; the church exercised a censorship over all thought, and all tendency to mental independence and originality was repressed. The empirical method of gaining knowledge, that is, the accumulation of facts by direct and careful observation and study of natural phenomena, was rejected. This method was too slow and laborious, and left too many blanks in knowledge, to be acceptable. The ancient and medieval philosophers preferred to construct complete schemes of the universe out of their own minds, and took such pride in these brilliant creations of their own intellects, and regarded them as so complete and perfect, that observation of nature was regarded as superfluous and unnecessary. Men engaged in fine-spun controversies over metaphysical and theological subtleties and dwelt on the unimportant and unreal trivialities of their subjective philosophies, to the neglect of the important and real things of the objective world. Schools were plentiful and vigorous; but they were under the ecclesiastical control and influence, and simply fostered the scholastic dogmatism and dialectics. There were men in those days with as great intellects as the world has ever produced; but they frittered away their gigantic powers on inane trivialities. Dogmas and authorities were rigidly adhered to, originality and innovations were repressed, and for centuries mental advancement was inhibited.

Medieval medicine displayed all these characteristics (scholastic medicine). The doctrines of the ancients, especially Galen and Hippocrates, and of the Arabians were rigidly followed, and until the Renaissance there was no change and no progress. Medical thought was dominated by the humoral pathology or theory of disease, which had appeared as early as in the writings of Hippocrates. According to this theory health consisted in a perfect combination and action of the elements and humors of the body, while disease resulted from a derangement or corruption of them. Four humors were recognized, mucus, blood, bile (yellow bile) and black bile (atrabile). Mucus was supposed to be secreted by the brain, and by flowing downward ("defluxions") into the respiratory and alimentary passages produced catarrhal and other diseases. Black bile was an entirely fanciful secretion of the adrenals. In crude or corrupted state the humors were supposed to be "acrid"—toxic or morbific; during the course of the disease they were believed to undergo a process of ripening or digestion—"coction" as it was called—to be finally expelled from the body at the crisis of the disease. The aim of treatment was to remove the acrid humors, or to promote their concoction and expulsion. Free bloodletting and other vigorous depleting measures were in general use.

About the sixteenth century began the great awakening of the world known as the Renaissance, which marks the end of the middle ages and the beginning of the modern era. This movement brought about a revolution in medical thought and yielded enormous acquisitions of medical knowledge.

The awakening in medicine was first manifested, in the sixteenth century, in the development of anatomical knowledge, as we have it to-day, under Vesalius (1514–1564), Jacobus Sylvius (1478–1555), Eustachius (1500–1574), Fallopius (1523–1562) and their successors, many of whose names are immortalized in our anatomical nomenclature more enduringly and more nobly than by monuments of bronze. The sixteenth century saw the labors of Ambroise Paré (1509–1590), the father of modern surgery, and important contributions in obstetrics and gynecology. In the seventeenth century modern microscopy was developed, and modern physiology may be said to have been founded by the epochal discoveries of William Harvey (1578–1657) relating to circulation and generation.

In the domain of internal medicine the Renaissance of the sixteenth century effected a revolution in, or release from, the rigid and dogmatic doctrines previously current. Nevertheless, the new doctrines were no nearer true or more effective than the old, and for three centuries longer internal medicine was destined to remain at a standstill before it too was really born into the family of modern sciences.

The first change was the overthrow of the authority of Galen (and the Arabians), which had previously been the main support of medical thought. This was brought about partly by the exact researches of Vesalius disclosing the errors in the anatomical teachings of Galen, partly by the effusions of the spectacular and mystical Paracelsus (1493–1541). The authority of Hippocrates continued to have weight for a much longer time.

Subsequent to Paracelsus and the break up of the ancient and Arabian medicine there developed a succession of speculative systems or schools of medical doctrine and practise, each of which had more or less general acceptance for a while, only to die out and be superseded by its successors (systematic medicine). These systems were developed by distinguished teachers or writers, were usually mutually antagonistic, and left but little impress of abiding value or truth upon internal medicine. The chief of these medical systems were as follow:

In the seventeenth century:

1. The mystical system of Van Helmont (1578–1644), in which such factors as the fall of man, spirits, demons and witches figured as causes of disease; this system was a sort of recasting of the doctrines of Paracelsus.

2. The Iatrochemical system, originated by Franciscus Sylvius (1614–1672), attributed the phenomena of disease to chemical causes (as excess of acid or of alkali); but the chemical ideas underlying the system were crude and fantastic.

3. The Iatrophysical (Iatromechanical or Iatromathematical) system, originated by Sanctorius (1561–1635) or more especially by Borelli (1608–1679), explained physiologic and pathologic processes as brought about by the physical and mechanical activities of the body structures, and employed precise methods for measuring those activities. This system had considerable following, and while it may have contributed to physiologic knowledge it was ineffective as a basis for therapeutics.

4. The system of Thomas Sydenham (1624–1689), of England, who largely followed Hippocrates.

In the eighteenth century:

5. The eclectic doctrines of Herman Boerhaave (1668–1738), of Holland; he was preeminently a clinician, and in his day was the most celebrated practitioner of Europe.

6. Animism, the spiritualistic system of Georg Ernest Stahl (1660–1734).

7. The system of Friedrich Hoffmann (1660–1742), based on the mechanical and motor activities of the body.

8. The system of William Cullen (1712–1790), based especially on the nervous activities of the body.

9. The "Old Vienna School," founded by Gerhard van Swieten (1700–1772), and having Maximilian Stoll (1742–1787) as a distinguished adherent; this school largely followed a humoral pathology, akin to the doctrines of Hippocrates, Sydenham and Boerhaave.

10. The doctrine of "infarctus," introduced by Johann Kämpf (published 1780), according to which diseases in general were due to fecal impactions (or "infarcts") and therapeusis was based on rectal irrigation.

11. Vitalistic systems, based on the activities of the "vital force," supported by Bordeu (1722–1776), Barthez (1734–1806) of the school of Montpellier, Reil (1759–1813) of Germany, Bichat (1771–1802) of France, and others.

12. Brunonianism, founded by John Brown (1735–1788) of Scotland, based on the doctrine that vital and morbid processes depend on irritability or stimulations varying in intensity. It continued into the nineteenth century, especially in Germany and Italy, and has the evil reputation of having been the most vicious and harmful medical system ever practised.

In the first third of the nineteenth century:

13. The theory of excitement, a form of Brunonianism, in vogue in Germany.

14. The Italian system of stimulus and contrastimulus, an offshoot from Brunonianism, developed by Rasori (1762–1837).

15. Homeopathy, founded by Hahnemann (1755–1843), first promulgated in 1810, and still surviving as an example of ancient medical beliefs.

16. Broussaisism, so-called "physiological medicine," founded by Broussais (1772–1838) of France, and in vogue for a decade or two from about 1816, which looked upon gastro-enteric inflammation and irritation as the cause of diseases in general.

Thus the history of internal medicine shows a succession of ephemeral systems and theories from Hippocrates down to about the second quarter of the nineteenth century. In the various systems that developed a few factors stand out prominently around which the theories centered. Thus, the fundamental distinction between spirit and matter, or between living and non-living matter, furnished grounds for basing medical philosophies on the spiritual (or vitalistic) principle or on material factors, respectively. Among the materialistic medical systems, some (the "solidistic" theories) were grounded on the solid structures of the body, others ("humoral" systems) on the body fluids; some ascribed vital processes and derangements to chemical activities, others to the physical, mechanical or dynamic activities of the body structures ("mechanistic" theories).

Although centuries after the end of the middle ages in other respects, the second quarter of the nineteenth century may be fixed upon as the approximate termination of the medieval period of internal medicine, since down to that time the dominant tone of medical thought was about the same as it had been throughout the middle ages, or indeed since the time of Hippocrates. There had of course been some advance since Hippocrates, as in the differentiation of various diseases and the discovery and introduction of remedial agents; moreover, the development of scientific anatomy, physiology and chemistry could hardly fail to have had a salutary influence on medicine. Yet the dominant conceptions in pathology and etiology and the rationale of therapeutic practise were practically not more advanced, more rational, or more efficient a hundred years ago than they were two thousand years ago. In the various systems that were propounded by the leaders in medicine, principles that were more or less true in a limited field were taken to be of universal applicability. Medical science and art can not, however, be reduced to one or a few general causes, laws and formulæ; each disease is a problem by itself, which must be worked out in all its aspects independently of other diseases. Hence the intellectual labors of a host of ingenious and talented thinkers for ages were wholly wasted, and effected no real advance in internal medicine, because they employed fallacious methods of thought.

Modern Medicine.—In the past seven or eight decades a radical transformation has taken place in internal medicine, pathology and therapeutics, which has put these subjects on the same high plane as any of the modern departments of science. There was no sharp dividing line of time between the old and the modern periods, but the new medicine developed gradually simultaneously with the decline of the old. The difference between the two depends on radical differences in logical method; modern medicine is developed by inductive, objective, empirical methods of attaining knowledge, the old doctrines were a product of theorizing and speculation. The evolution of modern scientific medicine has taken place along several independent lines of development.

The first branch of internal medicine to be elaborated on sound foundations was pathologic anatomy, its objective and obvious data making it facile of study. The pioneer in this branch was Morgagni (1682–1772) of Italy, whose epochal work on this subject appeared in 1761, when its author was 79 years of age. Other early workers in this field were John Hunter (1728–1793) of London and Bichat (1771–1802) of Paris. Bichat was followed by a brilliant group of French investigators during the first few decades of the nineteenth century, among the most eminent of which were Corvisart (1755–1821), Laënnec (1781–1826), Dupuytren (1777–1835), Andral (1797–1876), and Louis (1787–1872). The work of this group for a long time gave medicine a dominant pathologic-anatomical tone, especially in France.

The physical examination of patients by modern methods had its beginning in the introduction of percussion by Auenbrugger (1722–1809) of Austria. His method was published in 1761, but attracted no attention until it was revived by Corvisart (1755–1821) of France, who in 1808 published a translation of Auenbrugger's contribution which effectively brought it into use. The sister art of auscultation was introduced in 1819 by Corvisart's pupil Laënnec (1781–1826). Since that time there have been gradually developed the multitude of methods, physical, instrumental, chemical, microscopic and biologic, at present in daily use in the examination of the sick.

In the differentiation, clinical study and practical treatment of the various diseases much advance was made after the first quarter of the last century. The British physicians made especially valuable and numerous contributions in this field, displaying a practical and clinical bent contrasting with the dominant anatomical tone of the contemporary French school. In the last decade of the eighteenth century Edward Jenner (1749–1823) had introduced vaccination against smallpox. The second quarter of the nineteenth century was one of active development and many important contributions were made by the British clinicians, typically and brilliantly begun by Richard Bright (1789–1858), of London, who in 1827 elucidated the subject of renal diseases ("Bright's disease"). Among others eminent in this period were William Stokes (1804–1878) and Robert James Graves (1797–1853), of Dublin; and John Hughes Bennett (1812–1875), of Edinburgh, who was influential in bringing about the disuse of bleeding. The conceptions of continued fevers, which had previously always been vague and confused, were immensely clarified about this time by the differentiation of typhus and typhoid fevers as distinct diseases; this result was largely brought about by a contribution in 1837 by an American, W. W. Gerhard (1809–1872), of Philadelphia. Anesthesia with nitrous oxide was introduced in 1844 by Horace Wells, a dentist of Hartford, Conn.; with ether in 1846 by another dentist, W. T. G. Morton of Boston; and with chloroform in 1847 by Sir James Young Simpson, of Edinburgh.

About the middle of the last century the medical doctrines of the French school were introduced into Vienna by Rokitansky (1804–1878), who with Joseph Skoda (1805–1881) and others were pioneers in that development of scientific medicine in Austria and Germany which has attained such eminence. The identification of the cells of plants and animals by Schleiden and Schwann about 1838 opened the way to new conceptions of vital processes, and in 1858 Rudolph Virchow (1821–1902) presented his epochal doctrine of cellular pathology.

The discovery of the pathogenic rôle of bacteria and the development of bacteriologic science has been one of the most illuminating developments in the whole history of medicine, elucidating, as it has, the pathology of the large and important group of infectious diseases and vastly increasing the efficiency of medical and surgical treatment. Following earlier scattered discoveries, the great foundations of bacteriology were established by Louis Pasteur (1822–1895), of France, beginning during the fifties of the last century. The introduction of improved methods of research by Robert Koch (1843–1910), of Germany, about 1882, gave the science a vast impetus. The principal application of bacteriologic science has yielded incalculable benefits to humanity, as in the introduction of antisepsis by Sir Joseph Lister (1827–   ) during the sixties of the nineteenth century, of the specific serum and vaccine treatment of certain diseases, of prophylactic measures, and of the specific methods of diagnosis.

The tremendous and revolutionary advance made by medicine in the past few decades is obvious to the most superficial view. It is quite apparent that internal medicine has just been having its Renaissance, even within the lifetime of men now living having passed through that stage of development that other departments of human thought and activity passed through centuries ago. We have only just emerged from the middle ages in medicine. The movement is still in unabated activity. The final goal is far from having yet been reached, and there are vast fields in medicine yet to be cultivated before the one-sided and partial developments of the past will be amplified into a more symmetrical and perfect form. With medical research and progress continuing at the present rate, the outlook is rich with promise for the future development of medicine and added benefits for mankind.

In looking over its history we can distinguish the operation of two contrary tendencies or methods of thought which have controlled the evolution of medicine. These two principles mark off the history of medicine into two epochs, the speculative and the scientific, of a distinctiveness more fundamental than the ordinary division into such periods as the ancient, Arabian and medieval. These two factors are: (1) the subjective, deductive, a priori or speculative, and (2) the objective, inductive, a posteriori, empirical or scientific, methods of attaining knowledge.

The subjective or speculative method is the one that prevailed throughout medical history down to the modern era. It is far the more attractive and has much the stronger hold on human nature; it is the primitive and natural method of the untrained mind. It is easy and pleasant to construct complete schemes of the universe by introspection. Scientific investigation is tedious and laborious, and leaves many gaps in knowledge. There is a demand in human nature for certainty, and completeness, and finality in knowledge. Our patients, for example, demand this in our diagnoses and prognoses. The mind is impatient with the unknown, and is prone to fill up the blanks in knowledge by premature generalizations and assumptions.

The objective or empirical method of gaining knowledge is the one that characterizes modern science. Rigidly suppressing preconceived notions and bias, this method proceeds by painstaking observation and investigation to collect an adequate mass of objective data as a prerequisite to generalization. This method is not natural to human nature, but is a product of culture. In the history of mankind, it was ages before, in the Renaissance, it came to dominate the best thought; and among the mass of people at the present time it is only a cultured few who are thoroughly imbued with its spirit.

The utter futility of the speculative method as a means of attaining effective knowledge is completely demonstrated by the stagnation and inefficiency of medicine under its influence for thousands of years. The only sure and effective way of gaining knowledge is the empirical method, by patient observation and investigation, the tardy adoption of which was the sole means by which internal medicine has been revolutionized and vivified. The keynote of the true method was struck by John Hunter in his advice to Jenner when the latter was beginning to ponder on the subject of vaccination, "Do not think; investigate." The whole history of medicine is an imposing demonstration of the futility of theorizing and the utility of scientific investigation. This lesson should come home to every one of us, and indicate the only mental attitude we can safely assume. We should formulate our judgments only by the objective and empirical route. We should avoid dogmatism, premature theorizing, and generalization from insufficient data. We should frankly admit our ignorance, and not deceive ourselves or others by unfounded assumptions. We should practise a healthy skepticism, and carefully scrutinize the information offered us. No authority is too eminent, no traditions too ancient, to be exempt from criticism. The vast amounts of chaff in our professional literature need to be carefully sifted for the few kernels of truth; while to a far greater extent the ready acceptance of the interested representations of commercial establishments is a mark of naive simplicity and easy credulity. Always as the test of verity should be demanded the evidence of and agreement with an ample body of objective data. These considerations may seem trite, yet experience constantly demonstrates the necessity for their vigilant observance.

It is disquieting to reflect on the inefficiency and even harmfulness of much of the medical practise of the past. Yet our predecessors were men of sincerity and high ideals, and had the trust and confidence of the mass of the people. The therapeutic successes of the past must be construed mainly as an exemplification of the potency and action of psychotherapy.

Although the scientific method imposes rigorous criteria for the acceptance of doctrines, yet truths so established rest on a firm and abiding basis. For this reason we can feel confidence in the validity and permanency of such of our present medical theory and practise as has a thorough scientific basis. We have good reason to feel that at last we have attained some degree of finality in many of our doctrines; that the medicine of to-day is radically different from the ephemeral systems of the past and wherever thoroughly grounded on a scientific foundation will stand for all time.

If it be true that medicine has only just emerged from the middle ages, some medieval error must still persist in our doctrines and practise, which it behooves us to clear away. A keen criticism could doubtless disclose much of ancient error and fetishism in our materia medica and therapeutics and our pathological conceptions of obscure diseases. The entire profession does not even yet willingly and unreservedly accept the scientific element in internal medicine. The necessity and duty of thoroughly scientific methods in surgical and obstetrical practise is generally appreciated; but the obligation for equally thorough and scientific diagnosis and treatment in internal medicine is not so generally recognized. On the contrary, there is rather prevalent a spirit of disparagement and deprecation of what are called scientific methods, and insinuations are frequently made that they are not practical or useful. This spirit possibly arises not so much from frank conviction as from indisposition to keep fully abreast of the rapid developments in medicine, and a latent jealousy of those more advanced. That scientific methods in medicine (aside from those purely academic) are unpractical and useless is diametrically contrary to the reality; since it is such methods alone that have gained, and are gaining, and can gain for medicine all the real efficiency that it possesses. It is to me inconceivable that any methods in rational medicine can be other than truly scientific in their essence; sectarians, and laymen, and quacks can practise non-scientific medicine, but not true physicians. Our patients are entitled to the best possible service available, whatever be the character of any procedure that may be of use; and nothing short of this best is good enough for either the patient or the conscientious practitioner.

If a trained medical profession has only just found enlightenment, it can not be expected that the great untrained public will yet have emerged from medieval darkness in matters medical. The general public at the present time is actuated by the identical speculative spirit that for ages and until recently exercised its blighting control over the medical profession. A realization of this fact explains much that now seems anomalous and vexatious, and points the way of future betterment.

In many quarters the attitude of the public toward the medical profession is one of misunderstanding, distrust and antagonism. Fads and sects, like homeopathy, osteopathy and christian science, have a large and influential following, including the most intelligent and respectable members of the community. The hold which these (to us) irrational beliefs have on the public seems amazing and exasperating; yet the profession has only recently been emancipated from systems of precisely the same character—too recently for the public yet to have followed. Our customary attitude toward sectarianism is one of ridicule and denunciation; an attitude which produces infinitesimal results. These popular beliefs are not the product of perversity or wickedness, but result from powerful tendencies in human nature—the proneness of the mind to speculative thought; and the proper remedy is not vituperation, but education. With the diffusion of medical knowledge among the people—not by hysterical propaganda but by gradual and substantial enlightenment—which seems inevitable now that the profession can exert its influence from an unimpeachable basis, greater mutual sympathy and understanding are bound to come between the public and the profession.

In its rational development internal medicine is the laggard among the medical sciences, having always been centuries behind such branches as surgery and anatomy. This is natural, since the data of the latter are superficial and obvious, while those of internal medicine are deep-seated, obscure and inaccessible, and allow much play for theory or imagination. Moreover, internal medicine lacks the spectacular appeal which is exerted, for example, by surgery. Yet though its data are inaccessible, its problems difficult, its therapeutic possibilities limited, the greater the difficulties the greater is the glory of surmounting them, and it is evident that internal medicine has at last entered upon a career in honor and efficiency second to none.

SCIENCE AND SOCIAL PROGRESS

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SCIENCE is usually defined as a classified body of knowledge; but this definition implies a completeness in our knowledge which the present discussion can not assume. In considering the effects of science on social progress, it will be necessary to go back of the advanced stage of scientific thought and take account of positive knowledge in its beginnings, before it assumed the classified form. Science as here used, therefore, refers to the spirit of investigating phenomena, or studying facts, as over against the spirit of mere speculation and of superstitious belief. The growth of science represents not merely a new spirit or state of mind in society, but it presents an explanation of the universe based on intelligence and reason instead of the emotions.

The consequences of the growth of positive knowledge are so complicated and far-reaching that it is impossible to follow them in all their ramifications. Only their more general effects can be indicated. The difference between knowledge and ignorance seems at first to be sufficient to account for the entire difference between progress and stagnation; but such is not the case, for certain kinds of progress, such as those which result from selection, take place independently of science. The effects of scientific knowledge are of two kinds, those which influence the mind and those which affect the environment. The first effect of science is to expand the mental horizon, giving us broader conceptions and a more active mental life. This is especially true of astronomy, which tends to bring us out of ourselves by giving us enlarged ideas of space and time and by revealing something of the process of the creation of worlds; but the same thing is true of other sciences which reveal the phenomena of matter in our own world and teach the wonderful laws of life.

A second result of science, which has been emphasized by Fiske,[1] is that it gives man a conception of law, an understanding of true cause and effect. This not only helps to develop man's mind, but it has an immediate effect upon his conduct, removing it from the influence of superstition to the domain of reason. When man learns to separate real cause and effect from the mere sequence of events, he can adapt himself to external influences and avoid much suffering. He learns

[1] "Outlines of Cosmic Philosophy," Part II., Ch. XXI.; reprinted in Carver's "Sociology and Social Progress," p. 478.

also to take account of the future instead of confining himself entirely to the present. For example, when man understands the true nature of such phenomena as volcanoes, earthquakes and floods, instead of attributing them to the vengeance of an angry god, he is in a position to protect himself intelligently from their injurious effects.

A third effect of science is that it restrains and directs the emotional life. In helping to make reason instead of passion the guide of our actions, it has done more than seems at first apparent, even though at times it has tended to go too far in stifling the legitimate action of the feelings. Under the increasing domination of reason man has had a better perspective and has been able to discriminate between important and unimportant things. At the same time he has attained greater self control. Instead of giving way to blind passion he has acted with greater and greater deliberation. This increased power of discrimination and greater self-control have had a remarkable effect upon man's actions. In giving him greater toleration they have done much to decrease strife. Man is much less likely to go to war over fancied grievances or over petty differences. And in all kinds of activities man is much more likely to count the cost before entering upon them. He will not, from a passing impulse, enter upon great undertakings which are impossible of execution. Reason, therefore, in supplementing impulse, has done much to cause man to avoid destructive and useless activities and to economize time and strength in the pursuit of useful ones.

The final result of science upon progress is the one most generally recognized. Science is the basis of art, and the progress of knowledge has stimulated and perfected the useful arts. Science has enabled us to make great strides in the conquest of nature, and has made possible to some extent the control of different forms of life. The resulting increase of wealth has made possible far greater happiness and has opened new channels of social progress. This result of science is so far-reaching that only the general effects can be mentioned here, the more detailed results will be considered later in connection with the separate sciences.

As the progress of science has altered the course of human progress so materially in the past, and as it is likely to be the most important factor in determining social progress in the future, it will be of great advantage to study the immediate causes of the advancement of science, as well as the social conditions in which these causes are most likely to be active. The distinction between the causes and conditions of the advancement of science is not hard to understand, though it may not be possible always to follow the dividing line exactly in discussion. Science is advanced by individual effort, and stimuli to the individual form the immediate cause of its advancement. But these individual stimuli will act, or will act strongly, only under favorable social and physical conditions, and these last are what I have called the conditions of the advancement of science. They are a step farther removed from the product than the cause. As crops are cultivated in soils of different degrees of fertility, so science is pursued under conditions which are more or less favorable to its advancement; but science is not followed to any considerable extent, nor are the best results obtained, except under favorable social conditions.

The causes leading to the advancement of science are somewhat difficult to trace, so many and varied are the influences affecting the intellectual life. Doubtless our knowledge of science has been increased to some extent by chance discovery, but the amount of credit which should be given to this influence will depend upon our ideas of what is really accidental in discovery. The alchemists, in trying to produce gold from the baser metals, discovered a number of valuable chemical compounds. These discoveries were accidental in the sense that they were not the real objects of the researches, yet the compounds would not have been discovered if the alchemists had not been experimenting in the field of chemistry and with those particular chemical elements. Chance discoveries are seldom made far from the field which is attracting attention. Certain discoveries, like the properties of saltpeter, may have been wholly accidental; but such discoveries are rare. Therefore instead of making pure accident an important cause of the advancement of knowledge, it is more nearly correct to say that an unexpected element often enters into scientific discovery.

Another minor influence leading to the progress of knowledge is idle curiosity. Probably the early observations of the stars and the planets were due to little else. Few discoveries, however, can be attributed to this stimulus alone, although curiosity in some form doubtless enters into the majority of scientific discoveries. Professor Ward[2] quotes De Candolle as saying, "the principle of all discoveries is curiosity." But such an assertion gives us little help. Our task lies in attempting to discover the various influences which arouse curiosity. Mere curiosity, accompanied by no other motive, seems really to have had little influence in advancing science. It is true that students engaged in research may select one problem rather than another, simply because they have a greater interest in it; but their motive for investigating some problem is quite different from idle curiosity.

The greatest stimulus to the progress of science in its earliest stages is to be found in an attempt to achieve some great object. Although logically science is the basis of art, historically early art precedes science and is the greatest incentive to its advancement. The history of almost all the sciences shows that their beginnings lay in a desire to

[2] "Pure Sociology," p. 445.

attain some practical end, and in later stages also the same object still holds an important place. The desire to observe religious festivals regularly has stimulated the study of astronomy in order to obtain exact measurements of time. Among the Hindoos mathematics was stimulated by the requirements of religious worship in making their altars and laying out their courts. And according to Max Mueller[3] they also struggled with the problem of making a square altar of the same size as a round one. In Egypt, geometry got its stimulus from the need of parcelling out the land fertilized by the Nile. The progress of architecture also increased man's knowledge of mathematics and physics. The great European cathedrals were built before scientific works upon architecture appeared. It is said that the needs of Alexander's campaigns in Persia stimulated the study of mathematics and physics. And the desire to save human life has always been a great stimulus to the study of biology. These are simply a few illustrations of the kind of stimuli which have been most potent in the advancement of science.

After science has attained a start, if social conditions are favorable, it will progress without the immediate incentive of a practical need. As knowledge advances men begin to recognize its general value and try to extend it in every direction, believing in its ultimate, if not in its immediate, usefulness to mankind. This is science for the sake of science and is represented by the present period of scientific development. Such a method of increasing knowledge is never purely arbitrary, however. Not all truth is considered of the same value at a given epoch. If scientists have not always in view some practical end, they are more likely to be interested in those departments of knowledge which have a bearing on the immediate need of society. It will be observed, therefore, that this last influence, science for the sake of science, is not wholly separated from the preceding one, science for the sake of art, although a new motive is present. In addition to the need of solving an immediate problem, the value of all positive knowledge is recognized and becomes a new incentive in stimulating a study of the sciences.

With this brief enumeration of the chief causes of the progress of science, we may turn to the consideration of the conditions under which the pursuit of science is most likely to flourish. It seems probable that science is somewhat more likely to advance, at least after a start has been made, in cold or in temperate climates, than in warm climates. According to Professor Cattell's "Study of Eminent Men"[4] France has produced the largest number of scientists of any country, and England the next largest. This order is true not only in the absolute number, but

[3] "Origin of Religion," p. 142.

[4] The Popular Science Monthly, Vol. LXII., No. 4, February, 1903.

also in the percentages of the total number of eminent men. Italy surpasses all countries in the proportionate number of artists. If the ancient civilizations were included in this comparison, the supremacy of the north would not be so evident; but it is hardly fair to include the ancient civilizations, for when they were flourishing, societies in northern countries had not advanced. When northern societies did develop they produced their quota of scientists, though they did not produce their proportionate number of artists.

The chief explanation of any advantage which cold countries may have in the development of science is to be found in their greater needs. The environment is harder to subdue and at the same time man's requirements are greater, hence there is a continual incentive to improve the useful arts: and the attempt to improve the arts is, as has already been said, the most important stimulus to the advancement of science. In addition to this, life in northern countries seems somewhat better adapted to the development of a thoughtful people. In southern countries social life is more continuous and the conditions are therefore less favorable for meditation. In northern countries social life is interspersed to a greater extent with periods of isolation, and this condition is most favorable to the development of new ideas. A more completely isolated life, however, with little social intercourse would not be stimulating enough to develop new ideas. Of course the most desirable balance between the social and the solitary life may exist in particular cases in warm countries, but their general conditions for society, as a whole, seem to be less favorable than those of colder countries.

Physical conditions are, however, less potent than social conditions in stimulating the advancement of science as well as that of art. Three conditions in social life may be mentioned as especially important in preparing the way for scientific development. First, society should be far enough advanced in numbers and in wealth to have evolved a class with opportunities to devote their time to intellectual pursuits. This condition is brought about comparatively early in society by the caste or class system, and later is made much more effective by the system of division of labor. New societies cultivate science but little because they have neither produced a leisure class nor have they extended the system of division of labor far enough to permit individuals to devote their whole time to scientific pursuits. Secondly, a society should be active, for such a society undertakes new enterprises and stimulates society through the medium of the arts. Rigid societies, such as China and India, are satisfied with past achievements in knowledge, but when such societies become active, as in the case of Japan, they feel the need of devoting themselves to the acquisition and the extension of knowledge. Thirdly, social conditions should be such that man may easily free his mind from the influences of the past. He must emancipate himself from tradition. This is a different thing from what is commonly understood by freedom of thought. Under certain conditions men seem incapable of thinking outside of traditional ways, while under other conditions they may show great mental vigor in the face of severe persecution. As rigidly prescribed beliefs in society are usually due to the authority of religion, emancipation from theological restrictions must usually precede periods of mental activity. History gives us two well-marked periods of scientific advance, the Greek period of scientific thought and the modern period beginning in the sixteenth century, and both movements began under similar circumstances. In both cases emancipation from theological dogmas preceded scientific activity, and this emancipation was accomplished by the stimulating effects of geographical discoveries. In Greece some of the old religious myths were actually disproved by these discoveries, while belief in others was undermined by the enlarged ideas resulting from them. Similarly in modern times the intellectual life was greatly stimulated by the discovery of America and the circumnavigation of the globe; and the authority of the church was weakened by its strong opposition to the Copernican system. In 1616 the Inquisition issued an edict, which has never been repealed, declaring that to suppose the sun the center of the solar system was false and contrary to the Scriptures.[5] In the modern period of enlightenment, it is true that society was by no means stagnant when the discoveries were made; in fact, the discoveries themselves were due to an awakening intellect which may be traced to several sources, the chief of which is doubtless the travel and trade resulting from the crusades. Traced back to their source, therefore, it will be seen that the religious superstitions were themselves responsible for the movement which finally exterminated them. If the intellectual development of the Arabians is considered to be a third period of scientific growth, we shall find that that also was preceded by extended migrations and conquests, which affected greatly the active religious beliefs of the Mohammedan conquerors. The whole intellectual attitude of the Saracens changed after their conquest of Africa. Although in the three cases just cited geographical discoveries were responsible for the change in the mental attitude, no one event can be held responsible in all cases for the emancipation of the mind. If the forces of conservatism are very strong, a powerful social upheaval may be necessary to prepare the way for the reception of new truths. If, however, the intellectual condition is less rigidly fixed, milder influences may serve to stimulate thought. After scientific development has once begun, the succession of new truths themselves is the best guarantee against the excessive influences of tradition.

Ordinarily an active society will free itself from the bonds of tradi-

[5] "The Cambridge Modern History," Vol. V., p. 714.

tion. But that is not always the case, as is shown by the history of Spain during the period of intellectual activity which followed the geographical discoveries. Spain was an active country from the fourteenth to the sixteenth centuries, but its activity was not sufficient to overcome its intellectual conservatism; and this seems to be the reason why Spain took no part in the scientific progress of that period.

Professor Ward thinks the most important stimulus to the development of the mind has been the formation of the system of caste, because it produced a leisure class. A caste system is certainly important in the early stages of mental development, but such a society is likely to become conservative in its attempt to safeguard the interests of the leisure class. And when a caste system becomes rigid and traditional its usefulness is gone. If the idle class is also a priestly class, it is usually of service in preserving knowledge, but the very tenacity with which it clings to old ideas prevents it from discovering or accepting new ones. In the long run, therefore, a caste system has many disadvantages, and at no time is it so efficient in the advancement of knowledge as the system of division of labor.

Some of the conditions which help to stimulate science are also favorable to the production of art and it may be thought that all conditions favoring the two are sufficiently alike to cause science and art to develop together. But such is not always the case. Art, literature, and science developed in much the same period in France, and the same is also true of the Netherlands. Literature and science developed together in England. In the Arabian civilization also architecture, literature and science flourished simultaneously. In Italy, however, scientific activity followed art by at least a generation and it was relatively much less important. And in Spain science was almost disregarded when art and letters were cultivated with brilliant results. Furthermore, in Greece science developed at a considerably later period than art, and again in modern times science has made wonderful progress with only moderate achievements in art. The attainment of wealth and leisure is desirable for the development of both art and science and freedom from interference is essential for the best interests of both; but other circumstances may determine whether the intellect or the emotions will develop more fully. A society which is very rigid in its intellectual beliefs may produce a high grade of art in giving expression to those beliefs; or a society may encourage the fine arts while it does not develop the useful arts and hence does not give a special stimulus to the advancement of science. A wealthy luxurious upper class which may patronize the fine arts is likely to be conservative and intolerant of revolutionary discoveries. Scientific activity requires an underlying seriousness in the social life; and this was entirely lacking in Spain, for example, in the seventeenth century. On the other hand, young societies which are active are likely to show an interest in science before they make any headway in the production of the fine arts. The appearance of art requires an economic condition which produces luxury, and a social condition which will stimulate the emotional life; while science requires economic progress which will stimulate the useful arts and a social condition which will emancipate the mind from the domination of the past.

The discussion thus far has been confined to the origin and effects of positive knowledge in general; it now remains to consider the more detailed effects upon progress of the separate sciences. The origin, or at least the early development of the sciences, may in almost every case be traced to an attempt to improve the arts or to obtain some specific object, and the chief service to society of these sciences has usually been in solving those very problems which gave them their origin. A brief account therefore of the beginnings of the leading sciences will open the way to a discussion of their effects upon social progress.

Astronomy was one of the oldest sciences to take definite form, originating it is thought in Egypt or Chaldea, although China has very old astronomical records. In Egypt the study of astronomy was probably first stimulated by the phenomenon of the overflow of the Nile, upon which Egyptian civilization depended. The exact time of this phenomenon was a matter of importance and the passage of time was most easily marked by the movement of the stars. The first study of the heavenly bodies, made in order to mark the passage of time, soon led to a more detailed study for another purpose. It was noted that the Nile began to rise with the heliacal rising of Sirius. This coincidence was easily mistaken for cause and effect and if Sirius had such an extraordinary influence upon the affairs of men, the conclusion naturally followed that other stars must also have their influences. To ascertain the amount and character of these influences led to the study of astrology, which held man's attention for so long and enlarged considerably our knowledge of the heavenly bodies. In both Chaldea and China the desire to measure time accurately, as well as the wish to forecast the future, caused a careful study of the heavenly bodies. In Phœnicia the peculiar stimulus to the study of astronomy appears to have been the desire to obtain an accurate guide for traveling either by sea or land. The accurate marking of time, the requirements of travel and the desire to know the future were therefore the chief incentives for the study of astronomy, and the first two have been of continual service to society at all times.

The fact is worth noting that astronomy developed first in desert countries where the air is clear and the stars are easily visible the greater part of the time; in pastoral countries, too, where shepherds could follow the movements of the stars either out of curiosity, or to note the passage of time. Astronomy would have had an early origin even if it had not been for the overflow of the Nile, yet it is doubtful if it would have developed so soon under different atmospheric conditions.

The commonest laws of physics as well as the simplest movements of the heavenly bodies were known so early that we are unable to trace their sources. The Egyptians, again, were probably the first to study physical laws. The pyramid builders must have had a considerable mechanical as well as astronomical knowledge. Later engineering feats, such as the canal of Ramases and the various contrivances for controlling the waters of the Nile, would be considered creditable achievements even at the present day, and hence they show considerable advance in engineering skill and in knowledge of physical laws. Thus a knowledge of physics seems to be traceable in early times to building enterprises and engineering achievements.

In ancient times the subject of chemistry was cultivated in a practical way in the shape of metallurgy, the manufacture of colored glass and the dyeing of fabrics. But interest was early turned aside from these practical problems to the visionary one of transforming the baser metals into gold. This quest of the alchemists was begun in ancient Egypt and was continued through the middle ages until the scientific awakening of the sixteenth century. On the whole it was more of a hindrance than a help to the development of chemical knowledge. A more profitable study lay in the search for curative agents. This first took the fanciful form of a search for the elixir of life, but after the time of Paracelsus in the sixteenth century, a more scientific attitude was fostered and medicine became the chief medium for the advancement of chemical knowledge. Up to the nineteenth century the only laboratory of chemistry was the pharmacist's shop.[6] In comparatively recent times chemistry has found another incentive to progress in the desire to improve agriculture.

In their origins, chemistry and biology are more closely allied than any of the other sciences. Some knowledge of both animals and plants was of course gained in prehistoric times in the search for food. But in ancient civilizations and even down to modern times the one great stimulus to the growth of biological knowledge lay in the healing art. In ancient and medieval times almost all the contributors to biological knowledge were physicians with the possible exception of Aristotle, though it is doubtful if an exception should be made of a man who kept a pharmacy shop. At the Alexandrian museum the subjects of natural history and anatomy were carried on by the faculty of medicine, one of the four faculties originally established at the museum. In addition

[6] Wm. H. Welch, "The Interdependence of Medicine and Other Sciences of Nature," *Science*, January 10, 1908.

to medicine agriculture also forms a root for biology as well as for chemistry.

Psychology in early times had an indistinct origin in metaphysics, but as an inductive science it is of recent growth. In addition to the metaphysical problems which the study of mental processes was supposed to solve, two practical problems may be mentioned as stimulating the development of psychology. First the study and treatment of pathological mental states, which unites psychology with biology and chemistry in that all three have their origin to some extent in medicine. Secondly, the study of normal mental states and the course of mental development in order to improve the intellect and ameliorate human conditions through better methods of education.

As biology rests on the attempt to heal individual disease, so sociology arises from the desire to cure social ills and improve social relations. This statement would not be true of all the social sciences, especially economics, which found its chief incentive in the attempt to increase the material wealth of one social group at the expense of other groups. The general science of sociology, however, like that of biology, had its chief root in the desire to heal. The existence of poverty, crime, labor disputes, and similar problems has stimulated the desire to understand the principles of human association and the laws of social development.

With this brief review of the social origin of the sciences, we are prepared to consider in greater detail their effects upon social progress. In order to do this it will be advantageous to separate the sciences into three groups by diagonal lines, so to speak, the divisions not corresponding to the recognized boundaries of the different sciences. The first group includes astronomy, the greater part of physics and smaller parts of chemistry and biology. This group comprises what may be called the sciences of the environment. The second group includes a small part of physics and larger portions of chemistry, biology and psychology. This group comprises the sciences pertaining to individual life. Sociology and a part of psychology form the third group, treating of social life. If a larger number of the subsciences are included, the divisions would not be materially altered. A part of economics would be included in group one, as dealing with the environment; and a part of geology would fall into group two. These three groups may be designated for the sake of brevity as the natural sciences, the biological sciences and the social sciences, dealing respectively with the environment, with individual life, and with social life.

The historical development of the sciences is a complicated problem. Comte maintained that they developed in a serial order from the simplest to the most complex in the order of his classification—astronomy, physics, chemistry, biology and sociology. Spencer strongly opposed this theory and produced many facts to show that the serial order could not be upheld especially in the subdivisions of a science. Although Spencer appeared to have the best of this argument, there is, nevertheless, some ground for holding to the general principle expressed in Comte's theory. Following the three-fold division of the sciences, which I have given above, it seems clear that the sciences dealing with the environment developed before those dealing with life, and the latter group developed in advance of those dealing with society. This is, moreover, the order of their present degree of advancement as well as their early development.

The development of the sciences seems, in fact, to be influenced by two conditions, first the immediate interest of men, and secondly the complexity of the phenomena investigated. These two conditions account sufficiently for the relative growth of different branches of knowledge at different times. In early stages of civilization man's attention was concentrated chiefly upon the physical environment. To get a food supply and other necessaries of life more easily, to protect themselves against their enemies, to provide for the needs of the dead, and to satisfy the demands of the gods, were all important problems which stimulated a knowledge of the environment and brought at least a practical working knowledge of the simplest laws of mathematics, astronomy and physics, together with some knowledge of minerals, and of animal and vegetable life. The phenomena of life, the desire to live indefinitely and to overcome disease, attracted attention almost as soon as problems of the environment. But life is much stranger and more complicated than those objects of nature which may be readily examined, and a positive knowledge of the phenomena of life was much more slowly acquired. The heavenly bodies and other natural objects which were so far removed that their character was not easily perceived, and living things which were so complex that they were not understood, remained objects of superstition and speculation much longer than inanimate objects close at hand. The persistence of religious superstition delayed considerably knowledge of human anatomy and disease, favoring rather the pursuit of astrology and alchemy. The anatomical studies of the Alexandrian school were in opposition to the prevalent sentiments of the time, and the Mohammedan religion hindered the study of biology, as compared with other sciences among the Arabians. Biology, therefore, developed later than the physical sciences, not because it did not attract attention, but because it was too complicated to be understood in an early stage of mental development. The social sciences, on the other hand, developed last, both because they did not attract attention at an early period and because they dealt with complex phenomena. It is true, as Spencer points out, that some practical knowledge of social organization must have appeared at a very early time and conditioned, in a sense, all forms of progress. But this kind of knowledge was almost instinctive, and of such a nature as gregarious animals possess, or it was at least a product of gradual experience. For a long time social organization was not a subject of study like physical phenomena. Politics was the first social science to develop, if we may except ethics, which in its origin was connected with religion or philosophy, and was hardly an inductive social science. An interest in politics did not arise until different forms of social organization appeared and could be readily compared. A mere aggregation of people did not stimulate a study of politics, nor did more complicated organizations as long as they all rested on force. But when a change in social organization appeared possible, when different forms could be compared, and some were seen to be more efficient than others, social organization became an object of study. Under such conditions appeared Plato's "Republic," Aristotle's "Politics" and Machievelli's "Prince." Economics and other social sciences followed politics, but so difficult and complicated are the laws of association, that even with the present facilities for investigation, a general science of sociology can hardly be said to be established. The three comprehensive groups of sciences here outlined, seem, therefore, to have appeared in the order given in accordance with men's interests and the complexity of the phenomena to be studied; though it must be admitted that the subdivisions of the sciences did not develop according to their complexity alone. The additional influence of the immediate needs of mankind is strong enough to disturb materially Comte's theory of their historical development.

It is possible now to go a step farther and show that the growth of one group of sciences prepares the way both directly and indirectly for the growth of another group. The direct effect of the advance of one science upon others is a well-recognized fact and this influence is not by any means always in the direct order of their serial development, according to Comte's classification, but is frequently in the inverse order. A knowledge of physics has helped to advance astronomy as much as it has chemistry. This form of the interdependence of the sciences need not be enlarged upon.

The sciences have a less direct effect upon each other through the alteration of social conditions and the change of men's interests. Thus the earlier sciences have in a sense prepared the way for the later, and the development of the later sciences has often given a new impetus to the further advance of the older. The increasing knowledge of the physical sciences has produced two great results: First, it has increased man's power over nature, and, secondly, it has done much to free the mind from the bonds of superstition. The conquest of nature has increased the food supply, as well as other forms of wealth, and therefore made possible a larger population and permitted the concentration of population in small areas. This increase of population, however, which preceded an adequate knowledge of biology in the form of medical and sanitary knowledge, resulted in a high mortality rate, which is always a heavy drain on society, and therefore a great impediment to progress. Not only was the ordinary death rate high, but occasionally plagues swept over large areas making fearful havoc in the population. Authorities state that the black death in the fourteenth century took half the population of England. These pestilences were spread by the increased travel and trade made possible by the very progress which had been achieved in the control of nature. This period of the predominance of the natural sciences may be called the great period of natural selection. A denser population made possible by the increasing control of nature was held in check by a high death rate, uncontrolled because of the lack of medical knowledge. But these unfortunate conditions resulting from the unequal advancement of knowledge developed influences which were destined finally to reduce the evils. Disease and death have always seemed great enough evils to cause men to try to avoid them in more or less rational ways; but in a concentrated population these evils are brought forcibly to men's attention especially when they come in the form of a disastrous pestilence. Furthermore, increased association, which comes from a larger and denser population, is the chief means of developing sympathy and of arousing the desire to alleviate the sufferings of others. Hence the increased sympathy for others, and the more vivid realization of the amount of suffering in existence, became incentives for an increased effort to lessen the evils of disease. Moreover, other altered conditions caused these efforts to take a scientific turn. Previously superstitious beliefs had hindered the progress of science. Plagues were considered a visitation of the divine wrath, disease was treated with charms or with appeals to the saints, and the growth of anatomical knowledge was hindered by religious superstitions which forbade contact with dead bodies. But the new knowledge of the material world gradually lessened the hold of these superstitions and prepared the way for the scientific observation of the course of disease and the study of anatomy by the laboratory method.

In describing the effects of the natural sciences and the influences which have caused the development of the biological sciences, I do not mean to imply that the progress of knowledge has been continuous and uninterrupted, so that one particular period of history may be pointed out as having the conditions favorable for the origin of biology. There are a number of periods in which the forces here mentioned have been at work in greater or less degree and have influenced biological science. Perhaps at no time have they been more in evidence than at present, when, for example, modern conditions have turned people's attention to the ravages of tuberculosis, and have increased efforts to overcome this disease; or when the havoc caused by insect pests has become so disastrous as to cause a careful study of such forms of life in order to eradicate them. These influences, so clearly at work now, have, however, been in operation in greater or less degree since the sixteenth century. They were at work also during the later period of Greek civilization and had it not been for the persistence of religious superstition they would have been effective in the Arabian civilization.

Turning now to the effects of the biological sciences, three important influences may be mentioned: First, biological knowledge, through the prevention and cure of disease, has greatly decreased the rates of mortality; secondly, through the destruction of injurious pests and through the selection and cultivation of vegetable and animal life, it has multiplied and improved the food supply, and incidentally it has increased other forms of wealth. In these two ways then the sciences of life have made possible an increase in population at least as great as that made possible by the physical sciences. But it should be noted that the biological sciences are supplementary to the physical sciences. Both stimulate the growth of population, but the biological sciences do so without the suffering and waste prevalent before their development. Neither group can do its proper work without the other and each group has been a stimulus to the growth of the other. Sanitary measures could not be carried out without engineering knowledge, the present concentration of population would be impossible without sanitary precautions, and a large food supply would be useless without rapid means of transportation and communication. Finally, biological sciences have to some extent, and will to a greater degree, improve individuals and the race through selection and education. Medical science has been severely criticized because it has counteracted the effects of natural selection by making it possible for the unfit to live and propagate their kind. Without doubt a partial knowledge of the laws of life has produced some temporary evil effects along with the good. But the remedy lies not in a return to former conditions, but in the adoption of new methods through the perfection of our knowledge. Psychology has already enabled us to make rapid strides in our system of education and in our treatment of mental diseases; and a better knowledge of the laws of heredity and improved methods of social control will enable us consciously to improve the human species in ways most advantageous. And they will accomplish this more quickly and effectively than by the blind process of natural selection.

The past century may be regarded as preeminently a period of biological discovery, not because the physical sciences have not advanced also in a marked degree, but because biological discovery is the new factor which has been added to science to influence social progress. This new factor is destined to further in a wonderful degree individual efficiency and well being. It has already diminished human suffering and will in the future enable us to conquer some of the most serious evils still existing. But our rapid conquest of nature and our increasing control of different forms of life have introduced certain new evils which instead of being self-corrective seem likely to increase unless new forces in the shape of social sciences arise to correct them.

Mention has just been made of some of the undesirable effects of medicine in counteracting the forces of natural selection. The correction of this evil will not be found in biological science alone. A thorough study of the dependent, defective and delinquent classes must be made before an adequate reform can be begun and this study is an important department of social science. Modern ideas of humanity will never be satisfied with an indiscriminate production of dependents, soon eliminated by selective forces because they can not adapt themselves to the environment, even though the vigor of the population is kept up by this method. And the sense of self preservation will not long suffer the indiscriminate production of dependents who are kept alive as burdens upon the community and are even permitted to multiply and thus lower the average vitality and efficiency of a society. The only solution consistent with modern sentiment lies in studying the causes of the evil and applying the remedy at the source, so that fewer dependents will be produced and the average vitality of the population will be raised. This will be accomplished only through the cooperation of the sciences of individual and social life. Another evil effect of the unrestrained production of wealth and of the irrational propagation of human beings has attracted still greater attention and has probably been most influential of all in stimulating the study of sociology as a general science of society. The greater control over nature made possible by the advance of the natural and biological sciences and the increased wealth resulting therefrom, has affected different parts of society very unequally. Certain persons, who, for various reasons, had an early advantage in the accumulation of wealth, have been able to retain that advantage and even to pass it on to their descendants. In some cases, advantage once obtained has become cumulative. On the other hand the descendants of those who lacked special advantage, or were hindered with positive disadvantage, suffered similar and even greater disadvantage. And in the older societies the possibility of improvement through individual effort becomes more and more difficult. The resulting divergence of classes, which may have been useful in certain stages of social progress, is now seen to be out of harmony with the present trend of development. Society suffers because such a large number lack opportunity. Forces at work in progressive societies have, it is true, been lessening this evil, but modern sentiment now demands a more rapid change. And this desire has stimulated the study of sociology in order that the reform, which would evidently be radical, may be made in accordance with the natural laws of growth and with as little shock as may be to the social body.

Finally the social sciences supplement the natural and biological sciences by making their work more effective. The science of politics should perfect the general social organization and promote efficiency in all kinds of collective activity. The science of economics should aid in the conquest of nature by a better direction of the agents of production and exchange and should further human efficiency and well being by improving the process of the distribution of wealth. Similarly, jurisprudence, ethics and other social sciences should help to eliminate those who seek to prey upon society and should smoothe out the social relations of the rest.

The social sciences, therefore, the last of the three groups, contribute to progress by correcting certain evils left by the other sciences, by improving social conditions, and by perfecting social organization so as to increase social and, therefore, individual efficiency.

To sum up, the natural sciences developed first, because man was first interested in the conquest of nature and the simpler physical laws could be grasped at an early period. This period brought an increase of wealth but it was wasteful of human life. The desire to save life led the way to the study of biology and this study was made possible in a scientific way because of the enlightenment which came with the spread of knowledge. Knowledge of the physical environment and of life, however, did not prevent social disease from flourishing and did not greatly improve the social condition of a large part of society. To overcome these defects the social sciences within recent years have been cultivated with great seriousness. It is true that social conditions from very early times have been such as to demand a knowledge of the social sciences, but men's interests have not turned in that direction except in one or two cases, in a limited way. Interest in the social sciences has had to wait for the enlarged sympathies and the sense of solidarity which has appeared with the growing interdependence of dense populations, and these conditions have been dependent upon the advance of the other sciences.

With the cultivation of the social sciences, then, the chain of knowledge will be complete, at least so far as the needs which have already appeared are concerned. For each group of sciences will solve one or more of the great problems which man has encountered in the process of development. The physical sciences will solve the problems of environment, the biological sciences the problems of life, and the social sciences the problems of society.

ATTEMPTS TO EXPLAIN GRAVITATION

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TO the casual observer the heavenly bodies may seem isolated; but careful study will show how closely connected they are. Not only are they much alike in composition, but across the vast gulfs separating them they hold constant intercourse. Before the time of Newton the only influence known to pass from one heavenly body to another was what we now call radiant energy. To this Newton added a second influence, the force of gravitation. To this list we may also add a third, electrical attraction. The one with which this paper deals is gravitational attraction.

To the student who has at least an elementary knowledge of physics or astronomy gravitational attraction is one of the best known properties of matter; and it can just as truly be said that it is one of the least understood properties of matter, not only by elementary students but by mature physicists and astronomers. So often has the problem of gravitation evaded solution that some in despair have doubted the ability of the human intellect to grapple successfully with it. This feeling may have been strengthened by Newton's references to himself.

At present we can't tell how one body attracts another; and the science-producing value of the efforts made to explain the mechanism of attraction is not to be judged by the prospects afforded of ultimately obtaining a solution but by the stimulus afforded in furthering thorough investigation. What we want is a hypothesis that will conform to well-known phenomena and that will stimulate further investigation. It is needless to say that final solution finds no place in our attempt.

Most of the conjectures concerning gravitation have not reached the dignity of a hypothesis. Some of them seem even too wild for a romance. I think it is Schuster who has referred to his conjectures regarding gravitation as a holiday-dream. I like this word in this connection. However since they are the best we have let us make the most of them or supplant them with better ones.

Before reciting some of the attempts to explain gravitation it might be well to refer briefly to its discovery, magnitude, peculiarities, etc. Kepler had stated in his first law that the earth revolves in an elliptical orbit with the sun at one focus. With this knowledge at hand, by strictly dynamical reasoning Newton showed that bodies attracted according to a definite law (the attraction between two bodies being directly proportional to the product of the masses and inversely as the square of the distance, if the dimensions of the bodies are small compared with the distance between them). Having enunciated this law he proceeded to verify it by studying the motion of the moon. The moon revolves in an orbit that is nearly circular and to keep it in this orbit there must be an acceleration toward the earth equal to V^2/r where V is the moon's orbital velocity and r is the distance from the earth to the moon (approximately 240,000 miles). In place of V we may put $2\pi r/t$, where t is the time of one revolution (27.3 days). Hence the acceleration toward the earth equals

$$\frac{V^2}{r} = \frac{\left(\frac{2\pi r}{t}\right)^2}{r} = \frac{4\pi^2 r}{t^2} = \frac{4 \times 9.86 \times 240{,}000 \times 5280}{(27.3 \times 86{,}400)^2} = .0089 \text{ feet/sec}^2.$$

The acceleration the earth should exert, if Newton's law be true, at a distance of 240,000 miles (60 times the earth's radius) $= 32.16/60^2 = .0089$ feet/sec^2 where 32.16 feet/sec^2 is the acceleration at the surface of the earth. The verification in the case of the moon is complete. Hence we have the mathematical statement of the law: F (the force) $= Mm/r^2 \cdot G$ where G is a constant depending upon units only. We say nothing about the *quality* of the matter but only the *quantity*, and the *distance*. Notice also that there is no factor in the equation referring to the nature of the intervening medium.

It may not be out of place to call attention to the universality of the law. There are a few slight discrepancies between observed and calculated values, but as a whole it is fully attested by observation.

In referring to the magnitude of gravitational force consider first small bodies and later astronomical bodies. We know to-day that the radiation from the sun exerts a pressure. Kepler suggested this three centuries ago and one hundred and fifty years later the great mathematician Euler adopted his suggestion in accounting for the repulsion of comets' tails. So delicate is this pressure that it was not discovered until recently (1900). Albeit this pressure is very small as bodies diminish in size, we reach a limit at which it predominates over gravitation. This is due to the fact that gravitation is proportional to the mass (the cube of the linear dimension) while radiation-pressure is proportional to the surface (the square of the linear dimension).

When we consider electrons we find that the gravitational attraction between two electrons is insignificant compared with electrical attraction. The electrical force in air between two negative electrons one centimeter apart is equal to $(4.5 \times 10^{-10})^2 = 20 \times 10^{-20}$ dynes, if we take the charge on an electron to be 4.5×10^{-10} c.g.s. electrostatic units.

The gravitational attraction between two electrons at a distance of one centimeter $= 10^{-27} \times 10^{-27} \times 6.6 \times 10^{-8} = 6.6 \times 10^{-62}$ dynes, where 10^{-27} is the mass of a negative electron and 6.6×10^{-8} is the gravitational constant in the c.g.s. system. Comparing the two results, we see that the former is 10^{42} times the latter.

In astronomical bodies gravitation is the predominant force. An idea of its magnitude can be gained by calculating the attraction between the earth and the moon, which are small bodies astronomically speaking. The earth's mass is about 6 times 10^{21} tons, which is 80 times the moon's mass, and the distance between the two is about sixty times the earth's radius; hence the attraction $= 6 \times 10^{21} \cdot 1/80 \cdot 1/60^2 = 2 \times 10^{16}$ tons of force. To hold this system while it rotates about a common center would require about five million-million steel bars each one foot square and of tensile strength of thirty tons per square inch. Knowing the distance between the earth and the sun (23,000 times the earth's radius) and that the sun is about 330,000 times as massive as the earth, in like manner we can show that the force between the earth and the sun is greater than that of the earth and the moon. What must it be for double stars! Surely the origin of such gigantic forces ought to be worth careful study.

When Priestley and later Coulomb enunciated the law of electrical attraction (inversely as the square of the distance) they ignored the intervening medium. It was shown by Henry Cavendish, although not published, and discovered independently by Faraday that the electrical attraction depends upon the nature of the medium. If we take a piece of glass having a specific inductive capacity of six and separate two charges by this glass the force between them is only one sixth of what it is when they are separated by the same thickness of air. Strange to say gravitation is not affected by the intervening medium. This may be due to the gossamery nature of matter; that is, that the size of the molecules is very small compared with the distance between them.

So far as we are aware, chemical action, temperature and change of state are without effect on gravitation. No one has succeeded in demonstrating that it takes time for its propagation. If it is propagated in time the rapidity far exceeds that of light.

If we have two bodies electrically charged in a field and introduce a third body there is a redistribution. There is nothing analogous to this in gravitation, for the introduction of a third body in no way lessens the attraction between the other two. The earth's attraction is the same for me whether alone or in a crowd.

Thus when we compare gravitation with other phenomena about which at least we know a little, so great are the dissimilarities that it seems almost to fall outside the bounds of the physical realm.

Having briefly touched the discovery, law, magnitude, characteristics and peculiarities, we are ready to review the attempted explanations of the mechanism.

One familiar with modern electrical theories knows that the present tendency is to include everything in the electromagnetic scheme. Maxwell started this when he promulgated the electromagnetic theory of light. Experiment by Kauffman on the beta rays of radium lead us to regard mass as electromagnetic. Hence it is very natural to try to explain gravitation as an ether-phenomenon. This would require that the ether be capable of supporting enormous pressure or tension. In the older views the ether was regarded as a very attenuated medium. Such an ether can hardly meet the demands. Many modern physicists regard the ether as very rigid and dense when compared with ordinary matter. See Lodge's "The Ether of Space." If we follow Sir J. J. Thomson, who regards all mass as mass of the ether,[1] we can calculate the density of the ether, for the mass of an electron is about 10^{-27} grams and the volume is of the order of 10^{-39} cubic centimeters; hence the density of the ether is 10^{12} or a million million times that of water. When we consider the rapidity with which an ether disturbance is transmitted we see that the rigidity should be very great compared with ordinary matter. Taking the density of ether as 10^{12} and the velocity of ether waves as 3×10^{10} cms. per sec. the rigidity will be of the order of 10^{33} dynes per sq. cm., since velocity $= \sqrt{\frac{\text{elasticity}}{\text{density}}}$. The intrinsic energy if due to rotational motion will be of the order of 10^{32} ergs per cubic centimeter, if we assume the velocity of rotation is of the order of that of light; since the energy $= \frac{1}{2}$ mass times $\overline{\text{velocity}}^2$, where the mass of a cubic centimeter is 10^{12} grams and the velocity is 3×10^{10} cms. per sec. Hence the intrinsic energy and rigidity of the ether will probably meet the demands if we accept the views of ether and matter held by some of the greatest modern physicists.

If a falling body does not gather its energy from the ether where does it get it? Lift a ton to the height of 1,000 feet above the earth's surface and we have 2,000,000 foot-pounds of potential energy, or preferably a body that in returning to its original position will gather 2,000,000 foot-pounds of energy. Is this energy inherent in the body? Newton's letter to Bentley shows us that he was opposed to such a view. One thing is sure, there is no perceptible change in the mass and chemical composition of the body at the height of a thousand feet.

In the "Principia" Newton makes no attempt to explain gravitation, but in one of his optical queries he writes thus: "If the pressure in the medium is less in the neighborhood of dense bodies than at a greater distance from them, dense bodies will be drawn toward each other, obeying the law of gravitation if diminution of pressure is inversely as the distance."

Hooke, a contemporary of Newton and a man of great ingenuity,

[1] See Silliman, "Lectures," p. 51.

attempted a wave theory of gravitation from his observation that bodies floating on water agitated by waves were drawn toward the center of disturbance. The action of a body immersed in water was not considered. Since his time various attempts have been made to explain gravitation as due to a wave-motion. At the last meeting of the American Association for the Advancement of Science, Mr. Brush, of Cleveland, Ohio, presented a paper[2] in which he accounts for gravitation by ether-waves. His theory was doubtless suggested by radiation pressure. His theory demands an ether possessed of intrinsic energy. As before stated, the views of many modern physicists permit this. He assumes that this energy is due to waves; but the frequency is so much less than that of heat or light that molecules will not respond; and hence bodies do not become warm. He thinks that the energy of the ether is a generalized type whose degradation has been brought about by repeated absorptions and remissions. To substantiate this view he cites the case of the earth and the sun, in which rays of one length are absorbed by the earth and longer ones are emitted. He accepts the view of J. J. Thomson that all energy is kinetic energy of the ether. Before attempting to explain the mechanism of gravitational attraction he paves the way by referring to a well-known phenomenon in light. If we take an opaque body in a room with luminous walls it will experience pressure on all sides because we now know that light-waves have both energy and momentum. If we now introduce a second body each will be in the shadow of the other or will screen the other; and hence the radiation pressure is less on the side of each body which faces the other; and hence there will be a tendency for the bodies to be *pushed* together.

Now substitute for the light-waves waves of great length and less frequency, and owing to their low frequency they will affect the interior molecules as well as the surface ones, and hence we will have a volume or mass effect and not a surface effect as in light. This is in accord with Newton's law, for the force is proportional to the mass. "We may picture . . . molecules of matter buffeted about in every direction by ether-waves in which they are entangled, like a suspended precipitate in turbulent water." Now introduce a second body and the pressure in the direction of the line joining these two is less than in any other direction, as each is in the 'shadow' of the other; hence they are *pushed* together. Notice that according to his theory gravity is not a tension, but a pressure. Mr. Brush's theory, like all other theories regarding gravitation, is beset with difficulties. If gravitation is due to a type of radiation transmitted at finite speed it ought to be subject to aberration as is light. To avoid this Brush takes longitudinal waves and assumes the elasticity of ether is such that their velocity is much greater than that of light waves which are transverse. Longitudinal waves in the ether

[2] See *Science*, March 10, 1911.

have not yet been detected. However, this is no final argument against their existence as new and striking discoveries are being made every year. These longitudinal waves force us to conclude that the ether is at least slightly compressible. If compressible we are inclined, from our knowledge of matter to think of the ether as discrete or molecular. If discrete the particles are elastic and we have to postulate a second ether to explain the elasticity of the molecules of the first. This destroys the simplicity of the ether.

J. J. Thomson in his Silliman Lectures (page 160) enunciates a view somewhat similar to that given by Brush. In place of longitudinal waves he used short ether-pulses something like the Röntgen and gamma rays are supposed to be. This view presents the aberrational difficulty, as do other views which attempt to explain gravitation by a type of radiation. On this view any change in gravitation would be propagated with the velocity of light; and certain phenomena in astronomy require the gravitational effect to be propagated much faster than light.

Near the beginning of the paper we showed that the gravitative attraction between small charged bodies is very small compared with the electrical effects. Now if we assume that the linear equations of the ether are only approximate we may account for this relatively small gravitational effect from terms involving differentials of second or higher orders. Larmor[3] opposes this view because the introduction of higher order term not only disturbs the simplicity of the ether scheme, but also leads to optical dispersion in free space. If such dispersion exists it must be very minute, as bodies emerging from eclipses show no appreciable change in color. However, when we compare the gravitational force with the electrical force we see the former is so very small that the higher order term introduced to account for gravitation might give us a dispersion too minute for observation. But, as usual, we meet insurmountable difficulties. On this view the velocity of transmission would be of the same order as that of light; and while we do not know whether the speed is finite at all, we do know that if it is finite it greatly exceeds that of light.

Hence at present gravitation seems to be precluded from the electromagnetic scheme, owing to speed of propagation. Since in the last ten years we have tried to unify, it is unfortunate that it rebels against admission into our scheme. Many have pronounced it a mode of activity in the ether not specified but entirely different from the electromagnetic mode.

Replace Brush's long waves or Thomson's short electromagnetic pulse by rapidly moving corpuscles and we have Le Sage's theory. According to Le Sage space is filled with minute particles, ultramundane corpuscles, moving rapidly in all directions; hence a single body experi-

[3] See "Ether and Matter," p. 187.

ences an impetus on all sides; but if we take two bodies each screens the other and they are *pushed* together. Notice the force is one of pressure and not of tension. At first sight the impulse due to the impact would seem to be proportional to the effective area whereas according to Newton's law it ought to be proportional to the mass; but when we compare the diameter of a molecule with the distance between molecules, we see that only a small portion of the particles are arrested and that the number arrested is proportional to the number of molecules in the body (the mass).

The objections to Le Sage's theory are almost too numerous to mention. First and foremost, the enormous speed at which these corpuscles must travel not to resist planetary motion involves an enormous supply of energy from a source outside our universe. On this theory the source of gravitation is ultramundane. Again if these corpuscles are elastic there would be no screening action on the part of a body as the corpuscles would carry away their energy in reflexion. If the corpuscles are inelastic, bodies ought to increase in size. As the corpuscles transfer their momentum to bodies they lose kinetic energy, and according to Maxwell the loss sufficient to account for gravitation if converted into heat would keep the body white hot. Sir J. J. Thomson has shown that it is not necessary to suppose the energy is transformed into heat. In place of heat rays he suggests that the particles might give rise to a very penetrating radiation just as the cathode particles are supposed to give rise to the short ether-pulse known as Röntgen rays.

The fact that a physicist of Kelvin's rank has tried to patch up a theory that is so superficial shows how hard put to we are when we attempt to explain gravitational attraction.

About thirty years ago Zöllner explained gravitation on the assumption that the molecules carry positive and negative charges and the attraction between two unlike charges exceeds the repulsion between like charges. Lorentz, assuming a neutral body to be an assemblage of positive and negative electrons, has used the same hypothesis.

At Cambridge University during the fall term of 1908, Sir J. J. Thomson gave a course of lectures on "Ether and Matter" and in that course he devoted about three lectures to gravitation. Take two charged plates and in place of drawing the resultant Faraday lines of force (a Faraday line is a line beginning on a unit positive charge and terminating on a unit negative charge) consider the components (see Fig. 1).

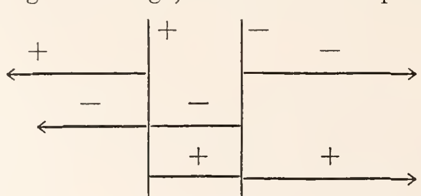

FIG. 1.

Outside the plates we have opposite effects in the same direction, hence they annul. Between the plates we have opposite effects in opposite directions and the effects are equivalent and hence cumulative. The tension will depend upon the number of lines and the closeness together. Each positive line will increase the tension of a positive line and a negative line will diminish the tension of a positive line. If a positive line increases the tension of a positive line just as much as a negative line decreases it, and if a negative increases the tension of a negative just as much as a positive decreases it, then the resultant tension between the plates will be zero, since there are just as many positive as negative lines. But if the effect (increase) of a positive on a positive is not the same as a negative on a positive there will be a resultant tension between the plates.

Now take an unelectrified body which we consider an assemblage of positive and negative charges. Lines of force will start on the positive charges and terminate on the negative ones, and just as there was a tension between the plates if the effect of a positive on a positive was not the same as a negative on a negative, so there will be a tension around this unelectrified body, if the above is true. Hence by making the assumption that the lines of force from a positive charge are not the same as those from a negative charge, the increase in tension of a positive on a positive is not the same as the decrease of a negative on a positive and we shall have a resulting tension. This might give rise to forces in the body of which the most important is gravitation. Here are Professor Thomson's own words taken from my class notes: "Matter I regard as made up of positive and negative charges. . . . Each unit charge is the termination of a line of force. I do not regard the positive and negative lines side by side as the same."

If you are looking for a Herculean task put the theory to test. Before starting let me remind you that the effect of the earth's field on an electron is something like 30 million times that of gravity and that it is not easy to screen a magnetic force. We see then that this theory is beset with difficulties before which the experimenter at present is helpless. Again, it complicates the simplicity of the electronic theory of electricity. Again, electrical attraction depends upon the medium. On this theory should not gravitational attraction also depend upon the medium? A summary of Professor Thomson's lectures on gravitation was published in Cambridge Philosophical Society Proceedings during the spring of 1909.

Various other theories have been promulgated but they must be passed by. Those interested in the subject will want to read Osborne Reynold's theory. Kelvin's hydrodynamical theory, which involves both the creation and destruction of matter, is rather unique.

Some despairing of ever finding a physical explanation have taken hold of Riemann's idea of space as a manifold. As this is wholly extra-physical and not in my realm I shall do no more than mention it.

Thus the phenomenon of gravitation remains a mystery; for so far every hypothesis made seems to have insurmountable difficulties. I am not sure that any of them shed light enough to even convince us that we are on the right track. It seems to have little or nothing in common with various other things of which we have some knowledge. A few years ago when radio-active substances were discovered, we found phenomena which at first did not seem to agree with well-known chemical and physical laws; but as experimentation progressed confirmation became more general and to-day many, if not all, the discrepancies have disappeared. Not so with gravitation. It still remains one of the least understood properties of matter. Probably if we could learn something of the mechanism of gravitation, that attraction between particles which only manifests itself at very small distances (cohesion) might be better understood.

Nearly two hundred and fifty years ago one of the greatest intellects connected with science turned his attention to gravitation. In that two hundred and fifty years physical science has made rapid advances. A boy who has completed a year's work in elementary physics could entertain Newton in electricity were it possible for the great philosopher to return to earth. After learning of the great progress in electricity, I can imagine him in his eager desire for knowledge turning to the boy and expecting some light on gravitation. Alas, not only the high school boy, but not even the most learned can give any definite information on gravitation. The problem is about where Newton left it.

THE PURPOSE AND SOME PRINCIPLES OF SYSTEMATIC ZOOLOGY

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SOME months ago, I had the opportunity of examining at my leisure an unpublished manuscript, dealing with a group of animals with which my own studies have made me familiar. At the same time, I had occasion to consult in connection with my work two publications, by different authors, concerning related, though not identical groups of animals. The contrasts offered by the three writers were so remarkable that numerous questions were raised in my mind, as to the motives that led to the investigations, and the principles that had governed them. So far as I can see, each paper may properly be classed as a contribution to systematic zoology and yet the three are totally unlike. In one of the published papers, the writer is wholly occupied with questions of names. He produces evidence to show that a given name is of earlier date than hitherto supposed, another is preoccupied, another was never properly defined, and still others have been erroneously used. Even though the results are disturbing, the facts brought out are interesting and the methods used are clever, but the questions arose in my mind—Is this zoology? Or is it history? Or what is it?—The other publication was utterly different. The author eschewed books entirely. He gave a series of descriptions of a number of what he designated as new species. The names he had given them were above reproach. The descriptions appeared to be lucid. The measurements seemed to be accurate. The locality from which each species came was given with more or less exactitude. But that was all! Not one species was commented on in any way. Not one was compared with any other. There was no more apparent connection between them than that between the books of a dealer's catalogue. And again the question forced itself on me—Is *this* zoology?—The manuscript which I examined was strikingly different from either of the published articles and yet it certainly had features in common with each of them. There were frequent references to books and names, there were descriptions of new species, and in neither respect did the writer show greater learning or skill than the authors mentioned. Yet the significance of structures and the interrelationships of the species were so illuminatingly treated that I never felt any doubt that the work was really zoology, or that any zoologist would fail to acknowledge its value. But the point of view and the methods of the writer seemed so different from those of the other authors, that this question arose in my mind—Is it fair to call such work systematic zoology? And so, naturally, I fell to considering the purpose of systematic zoology and the principles which should govern it.

A century ago any one who was a zoologist was, almost of necessity, a systematist. Although Lamarck is now perhaps best known for his contribution to philosophical zoology, he was preeminent in his day as a systematic zoologist, and in some groups of invertebrates his work may be regarded as forming in large part, if not wholly, the foundation of our present classification. So too Cuvier, famed as a comparative anatomist, left as his chief monument, the great systematic work, "Le Règne Animal," in which the results of his anatomical studies were fittingly summarized. But in the days of Lamarck and Cuvier, as Agassiz pointed out in his "Essay on Classification," the fauna of Europe, so far as the larger animals were concerned, became so well known that men with a love for zoology, but without means of securing collections from foreign lands and not attracted by the minute forms of life, turned from the describing and classifying of animals to a more intensive study of those already well known. Not only did anatomy receive more adequate attention, but the habits of animals and their relation to their environment became subjects of investigation, while under the inspiring leadership of Döllinger and von Baer, embryology, virtually a new field, was opened to investigators. Then came the days of Lyell, Agassiz, Darwin, Wallace and their many illustrious contemporaries, and zoologists began to realize the magnitude of their field and the multiplicity of its problems. No such sudden enlargement of the field for zoological research had ever occurred before and probably never will again. It was natural, therefore, that many zoologists working on the frontiers of the new territory should not merely lose sight of their fellows, who had not traveled so far, or who had journeyed in different directions, but should also lose sympathy with them. Although the lazy, the easy-going, the incompetent, do as a rule lag behind when a new country is opened, those who remain in the old fields do not usually do so from laziness or incompetence, Charlatans and self-seekers are conspicuous in frontier communities, but, of course, the majority of those at the front are not such. A man's motives may be the highest and the quality of his work the best, regardless of whether he remains in the old fields or seeks to push the frontier further on. In any case, however, he should know what he is trying to do and why he is trying to do it. He should be ready and willing to give a reason for the faith that is in him—faith that the work he is doing ought to be done and that it is *his* work. It is eminently fitting, therefore, that we who are still busied with systematic zoology should make clear our central purpose and formulate some of the principles that guide us in our work. In attempting to do this, I am obviously speaking only for myself. I could not, even if I would, express another worker's motives or principles. The excuse for publishing my own is two-fold; the thought that they may be in some way suggestive to other systematists, and the larger hope that they may serve to increase the mutual sympathy between all classes of zoologists.

There seem to be at least three current opinions as to systematic zoology. One is that it is engaged in the vast undertaking of cataloguing the animal kingdom. Every species of animal must be listed and hence must have a name, or, at least, a number. That the names may be attached to the right animals, descriptions and figures must be published. As there are still an unknown number of unnamed species, the describing of new species is the most important part of systematic work. The remainder consists of arranging in some sort of comprehensible system the thousands of names already in use. This type of systematic work is well shown in Linné's "Systema Naturæ," the purpose of which is, frankly, to give a complete catalogue of all natural objects. The confidence that such a catalogue would be immensely useful for many purposes was a sufficient incentive to undertake the labor involved.

A second opinion of systematic zoology, which has found expression several times since the opening of the twentieth century, is at the other extreme from the preceding. This very modern view is that systematic zoology covers the whole field—morphology, physiology, embryology, histology, paleozoology, even cytology are but assistants in systematic work. As taxonomic characters occur obviously on the exterior, so they occur no less really, though obscurely, in the internal structure, in the performance of functions, in the tissues, in the development, even in the mitotic figures in the cells. As comparative study of recent animals is essential to a proper understanding of character values, so the careful study of fossils and the revelations of the geological record are supremely important for systematic work. According to this view, the systematist is not the assistant erecting the scaffolding with the aid of which the real building is to be done by the other specialists, but he is himself the master-builder and the others are the carriers of material with which he may build.

The third opinion of systematic work, held in some degree by many zoologists, though often more or less unconsciously and seldom openly avowed, is that it forms an elementary sort of study which has a certain educational value in training the eye and the judgment of those who are to become zoologists. It bears much the same relation to zoology proper that arithmetic does to what we call higher mathematics, and the really able man will not delay in it, after he has secured the training it affords. It is preeminently the field for the amateur and the untrained worker. According to this view, a piece of systematic work may well be a part of the training of all professional zoologists, but capable men will naturally go on into the supposedly more fertile fields of physiology, cytology and experimental zoology.

As is usually the case where diverse opinions clash, a measure of truth is to be found in each one of the above-mentioned three, and doubtless there are other views more or less equally true, to which I have given no expression. As a systematist I should be very glad if I could bring myself to believe that the second view, formulated above, is essentially correct but the more I have thought on the subject the more strongly I have felt that it claims too much. It juggles with words and distorts some inescapable facts. On the other hand, every systematist whose zoological horizon is not hopelessly limited must reject the first view as utterly inadequate, while he will very naturally resent the implications of the third. There can be no question that so far as it goes the first view is true; naming species and cataloguing them, and even determining the correct names to use, are a conspicuous part of systematic work still. If, however, the systematist goes no further, he can not expect high rank as a zoologist. He ought not to ignore the significance of his observed facts; he ought to welcome, even if he can not seek for, information from each and every part of the field of zoology. If he neglects or refuses to listen to the suggestions of physiology, embryology or paleontology, he is not worthy of his task. And this, it seems to me, is the very real truth in the second view mentioned. In the third view, the vital fact is that good systematic work requires more than ordinary training of the abilities to see, and to estimate the relative worth of the facts observed. It errs in assuming that a mind so trained can not find an adequate field of usefulness in systematic zoology.

Combining the above-given truths, we find we are still far from expressing the central purpose of systematic zoology. We have only brought together a statement of certain means to be used, of certain sources of material and of certain abilities required. The end in view is hardly suggested. As the purpose of zoology is something beyond the mere knowledge of all the phenomena of animal life, seeking further the true interpretation of those phenomena and even further to the ultimate interpretation of life itself, so it seems to me, the purpose of systematic zoology reaches beyond the mere increasing of our knowledge of animal forms and seeks a true interpretation of the resemblances and differences which we find among them. Primarily, however, it deals with results and is only indirectly concerned with the methods by which those results have been attained. It deals with the travelers, the routes traveled and the destinations reached in the animal kingdom, but it leaves for other zoologists to determine the means of transportation and the causes of the traveling. Briefly we may express the motive thus:

The purpose of systematic zoology is to determine the racial characteristics, and to set forth clearly the mutual interrelationships of animals.

The validity of this statement will not be affected, I think, by either the size of the group with which the systematist may deal, or the phase of the subject which specially interests him. It applies just as well to the man who specializes in a single genus as to him who attempts to comprehend a whole order or class. The only difference is that the smaller the group, the more the worker may hope to attain his purpose, at least to some degree. The larger the group the less is it possible for the purpose to be attained. Nor does it matter whether the systematist is especially interested in new species, or in the morphology or life histories of old ones, or in the geographical or geological distribution of animals. If his purpose is to determine more accurately the racial characteristics, or to make more clear the interrelationships, of the animals with which he deals, the value of his work as systematic zoology, at least so far as it is reliable, can not be questioned. And should the day ever dawn when it can be fairly said that the purpose of systematic zoology, here formulated, has been attained, we shall have, not merely a complete catalogue, but a complete history of the animal kingdom.

Having thus defined what seems to me the purpose of systematic zoology, I hope I may be pardoned if I attempt to formulate some of the principles which it seems to me ought to govern such work. And I may say at the outset that few inexperienced workers appreciate the difficulties involved. It is no uncommon thing to hear systematic work and workers severely criticized for the instability and uncertainty of their results. Such critics forget that nature is essentially unstable and that the fundamental difficulty of the systematist is the continual variation of the material with which he deals. No doubt much descriptive work has been poorly done and unfortunately it is true that in the past some systematists have ignored their predecessors and their colleagues. But at the present day descriptive work is, as a rule, well done and is often accompanied by most accurate figures, while ignoring the work of others is remarkably uncommon and is very rarely intentional. Nature, however, is as variable as ever and the best of descriptions and figures can not deal adequately with her marvelous diversity. Moreover, in addition to the inherent difficulty of variation in his material, the systematist has to face the even more exasperating difficulty of variation in human judgment. Not only do the judgments of his non-systematic colleagues differ from his own, but on any given point the best trained students of his particular group are quite likely to differ from him and from each other. Still worse is the indubitable fact that his own judgment varies. What seems to him well-established at one time may a few months later be incredible, not so much because of new facts bearing on the matter, but because his horizon has enlarged or his point of view become fundamentally changed. As long as nature and human judgment are what they are, it is hopeless to look for perfect stability even in as artificial a thing as nomenclature, except by arbitrary decisions adopted by practically unanimous consent. No code can be devised which will meet all the needs of the case, and most zoologists will continue to call a holothurian a holothurian in spite of the codes, until it is arbitrarily agreed to call it something else. I can not see that the proposed substitution of numbers for names would tend to either greater simplicity, intelligibility or stability. The difficulty is not with the names we have given, but with the objects we have named and the judgments which interpret our definitions. Recognizing then these two fundamental difficulties at the very base of systematic work, I venture to suggest a few principles which would, I think, if universally adopted, increase the clarity and stability of our results. They are more or less generally accepted even now, and I claim no originality in setting them forth. I only hope their formulation may lead to more extended recognition. The first one may be expressed thus:

Naming and describing new species and correcting nomenclatural errors, while valuable and indeed essential, is frankly the most elementary and hence the lowest form of zoology.

The zoologist who, like myself, enjoys collections and finds an unceasing interest in the diversity of animal forms, very easily overlooks this principle, though he will rarely question it when fairly stated. He will grant that after all, names are but handles by which the ever-increasing number of animal units may be shifted and turned and made use of in zoological building, and he will probably admit that the handle is not so important as the unit. It would be well if we went further and acted on the principle that the smoother a handle is and the more perfectly it is adapted to its object, the better and more usable it is. A clumsy name or a meaningless name or a name that has no natural and inherent association with the object is not a desirable name, for it is not a well-formed handle. This is why, in my judgment, the use of the names of persons for zoological units is to be deplored. They rarely have any inherent association with the object, and after a short time they have no significance whatever. Any one looking at the animal can see why a certain oddly shaped sand-dollar was called *Rotula dentata,* but how many of us know who Rumphius was that the same animal should have been called by another writer *Rotula rumphii?* The use of place-names has more justification, especially for insular or local forms, but it has led to many meaningless or misleading names and is seldom to be recommended. There can be no doubt that badly formed and inappropriate names have been a just cause of much of the criticism of systematic work. The correcting of errors is always an ungracious task, especially where the errors are apparently trivial and obviously unintentional, and this is particularly true in systematic zoology. No reasonable person will, however, question the necessity of it or refuse to accept the correction if it is justified. But in such work, accuracy of statement, soundness of judgment, clearness of reasoning and perfect courtesy are required to an unusual degree. These qualities are, of course, essential for the best scientific work of any kind, but they are particularly so in systematic zoology, where so much work is of an elementary nature. The lack of one or more of them has depreciated the value of many an elaborate monograph. On the other hand, their presence does not alone guarantee the worth of a piece of zoological research. And this suggests the second principle I desire to emphasize.

To be of real worth and permanent value, the systematic study of any group of animals must take into account, so far as they are known, the pre- and post-natal development, the geological history and the geographical distribution of the species which compose it.

A systematic study of any group of animals which considers only the adults, even if the morphology, physiology and habits are all taken into account, can not be regarded as complete. Nature would indeed be a puzzle and interrelationships a hopeless snarl, if the stages of development were not discoverable or were meaningless. It is incredible to me that any zoologist, who has examined the evidence at all, can deny the existence of stages in both pre- and post-natal development or question the fact that those stages have some meaning. And I am unable to believe that we can even approximate the true history of any group of animals so long as those stages are ignored. Equally important is the paleontological evidence and to ignore it when it exists in any appreciable amount is indefensible and may result in deplorable error. For some reason the relationship of systematic zoology to geographical distribution has been more generally recognized than its relation to paleontology, but it seems to me obvious that in the diversification of the animal kingdom, the element of time has been fully as important as that of space. In neither case, however, is it justifiable to assume that quantity (of either time or space) is necessarily correlated with specific qualities. Discontinuous distribution, either geologically or geographically, ought never to be regarded by itself as a differential character. Either may be used as an additional character for a group otherwise structurally distinguishable, but no species (or other group) ought ever to be recognized whose identity can not be determined without knowing the locality or the geological horizon from which it came. To act on any other principle can not fail to lead to serious confusion. In view of all the evidence then which must be taken into account, it is clear that the final decision on the validity of any group must be rendered by the systematic workers in the larger group to which it belongs. It is not to be expected that physiologists or experimental zoologists or even entomologists can decide as to either the validity of a species of sea-urchin or the desirability of a genus of birds. And this leads to a third principle often overlooked.

While genera and larger groups in our systems of classification ought to be based on relationship, their delimitation is often of necessity artificial and is purely a matter of expediency or convenience.

The English zoologist Duncan maintained that it is "impossible to admit genera which are not differentiated by characters which have a decided and important physiological value." Other zoologists have ignored or distinctly repudiated this view. The difference of opinion seems to be based on a difference in the approach to the question and it is to this same difference of approach that all discussion as to the relative merits of large and small genera is due. The zoologist who is particularly occupied with the diversity of species and who has examined large numbers of individuals in the attempt to establish specific limits becomes impressed with the great importance of constancy in any given character and, when he finds a group of species which possess in common a character, or certain characters, constantly maintained, he finds it desirable to designate them by a common name and the group is to him a genus. Such a process naturally leads to numerous small genera. On the other hand, the zoologist who studies, from the morphologist's view point, relatively few specimens, representing perhaps many species, is naturally most impressed by the resemblances, and he finds that as regards characters which to him seem of physiological importance, his material divides into comparatively few groups. These he designates as genera and since the minor characters reveal a more or less marked differentiation into species his genera are naturally large. It seems to me that the difficulty is the same as would arise were one trying to decide what is a branchlet on a tree. In certain old, nearly dead trees, or in very young ones, there might be little difficulty, main branches, secondary branches, branchlets and twigs would all be sufficiently few to be distinguishable and there would be little disagreement as to the limits of the branchlets. But in most trees this would not be the case and much would depend on whether one began at the twigs and worked downward or at the branch and worked upward. In other words, while genera are, or at least ought to be, natural groups, their limits are often necessarily artificial and arbitrary. We recognize them by name for convenience and their limitation is largely to be determined by expediency. To say, as Duncan does, that it is "impossible" to recognize certain genera is an exaggeration, however inexpedient we may deem such genera to be. Wherever the number of species in a genus is, by the extension of our knowledge, so increased as to make the group unwieldy and more or less heterogeneous, it may for convenience be divided. Whether such divisions are called genera or subgenera is again only a matter of expediency, but for my part I have never been able to see the merit of subgenera. If a group of species is not marked by sufficiently constant characters to make it recognizable, it is not entitled to a name, and if it is so marked, I fail to see why it should not be called a genus. I do not think the description of a tree would be made more lucid by an attempt to recognize sub-branchlets. It is true that the extensive use of subgenera would permit a corresponding decrease in generic names, but I do not think this would be any real advantage. We may as well face the fact that it is no longer possible for any one man, unless he be rarely gifted with the right sort of a memory, to know the principal genera of all classes of animals. Our knowledge of the animal kingdom has so expanded in the last thirty years, that even if a man specializes in the most elementary form of systematic zoology, he can not hope to have a comprehensive view of all known genera. No one will deny that this is to be regretted, but while the fault may be in part due to our systems of nomenclature, the chief blame must rest on nature and the curiosity of zoologists. The diversity of animal life and the zoologist's insatiable desire to continually increase our knowledge thereof are at the root of the trouble. It has been said that the general lack of interest in natural history among the people at large is due to our complex nomenclatural system. I doubt if interest in natural history is any less now than it has been in the past, but if it is I do not believe the fault is with our nomenclature. Granting, however, that it is, I do not see how the difficulty can be avoided. When we are told that the would-be naturalist knows a robin as *Turdus migratorius* and it is unfair to him to so divide *Turdus* that the robin has to be called by some other name, we can only reply that the inconvenience and annoyance of giving up the old name are obvious, but the progress of our knowledge of thrushes in their specific diversity has shown that the robin, when compared with the original species of the genus, is not a *Turdus,* and it is therefore inaccurate, to say the least, to continue to use that name. And in scientific work to be inaccurate is a more serious fault than to be annoying. The importance of accuracy in systematic work suggests a fourth principle which may be expressed as follows:

The value of a character for distinguishing species or higher groups depends chiefly on its constancy, and for indicating relationships within a group on its significance; in neither case is its conspicuousness anything more than a matter of convenience.

Few zoologists realize that the usefulness to the systematist of any characteristic of an animal depends on the end in view. Since species are the units with which our work is chiefly done, their most usable characters are those which will readily distinguish them from each other. But when we try to arrange them in genera and show the natural interrelationships of any group, the characters in which they are alike are of far more importance than those in which they differ. For defining species then we are often justified in using characters which seem to us trivial and of no significance. Not infrequently newly proposed species are condemned because the characters on which they are based are said to be "so trivial." When this criticism is examined, however, it will be found that it really confuses two very different things which may be illustrated as follows. A newly described bird is said to differ from another species in having the iris white instead of brown and the tail feathers tipped with cream-color instead of yellow. Such differences are certainly trivial, but experience has taught us that the color of the iris rarely, if ever, shows such a degree of diversity within a single species, and if the examination of a fair amount of material shows the two characters given to be constant, the validity of the species can hardly be questioned. If, however, the new bird is said to be characterized by a longer bill, a more markedly yellow tinge below and a greater amount of yellow on the tail feathers, these characters would not only be considered trivial but we should be justified in being skeptical of the validity of the species because experience has taught us that such characters are subject to very great diversity. If new species are to be condemned, then accuracy demands that it shall not be because the characters assigned are trivial, but because they are inconstant and hence unreliable. When we come to genera, however, while it is of course desirable that the characters should not be trivial in any sense, the essential point is that they should have some significance, either historical or physiological. These two terms are not synonymous, for such a structure as the vermiform appendix in man has a historical, though apparently not a physiological, significance. Usually, significant characters are more or less conspicuous, and I am strongly inclined to believe that where they are internal, or otherwise difficult to ascertain, they are associated with external, or in some way obvious, characters. The formation of genera based on larval characters, or those of some other special stage of development, is greatly to be deplored, and I have no doubt that if such groups really represent natural relationships, differential characters will be found in the adults. If they are not, it seems to me clear that, notwithstanding the possibilities of what we call "parallelism" and "convergence," the characters of the special stage are temporary adaptations of variable significance. It is impossible to designate any character or group of characters which may be relied on for systematic purposes in all groups of animals. Certain characters of remarkable constancy or obvious significance in some groups are quite unreliable in others. Color is a conspicuous illustration of this important fact, for in certain groups it is very constant, or has some very evident significance, while in others it is so inconstant and diversified that it is of no use to the systematist. And this remarkable difference in the value of color may occur within the limits of a single genus. Only by extended knowledge of a group can it be determined what characters are of value for either the differentiation or the grouping of species. It is perfectly proper to speak of questioning the *validity* of a species and its validity must ultimately be determined by the constancy of the character or group of characters supposed to distinguish it. But it is not correct to speak of questioning the "validity" of a genus. Its desirability and the accuracy of its definition may either or both be questioned. One genus is as "valid" as another but the desirability of naming any group is a matter of opinion. And this brings us to the last of the principles I wish to formulate.

In all systematic work, the line between facts of nature and opinions of the worker should be sharply drawn; the value of the work often depends on the clearness of this line.

One of America's greatest zoologists was wont to repeat over and over again to his students these words: "The assertion that outstrips the evidence is a crime." Like most aphorisms of the kind this sentence needs some qualifications, but zoologists will hardly question the modified form that "the assertion as a fact, of what is really only an opinion, is a crime." The more unqualified the assertion, or the hazier the opinion, the greater is the crime. The opinions of a writer, particularly if based on careful observations and long experience, may be as valuable as his facts, but it ought never to be possible to confuse the two. It should be the aim of every systematic zoologist to set forth his facts so distinctly and so unmixed with opinions that any qualified worker may form accurate opinions for himself, and to so express his opinions that the justification for them in the facts of nature may be clear to all.

Having thus set forth what seem to me five of the most important principles of systematic zoology and realizing the possibility of varied shortcomings of my own with reference to them, I can only add in conclusion, as indicative of my repentance, *Peccavi.*

THE NARROWING CIRCLE OF THE ANIMAL KINGDOM

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IN the older regions of the country the scarcity of animals and birds has been noticed and studied for a long time, but many persons are unaware of the rapid decrease in bird and animal life in recent years. From the timbered regions of the far west, that region which was thought to contain inexhaustible supplies of game of all description, we are constantly hearing such queries as; "What has become of our Rocky Mountain goats and sheep, which were once so conspicuous on the cliffs of the Rockies? Where are the elk and other deer?" In Maine the same questions are being asked concerning the moose and caribou; while the whole country is wondering why the birds are disappearing so rapidly.

The question has aroused the government, as well as the naturalists, with the result that numerous investigations and reports have been made. Any one who has taken the trouble to do a little investigating along this line, if he has done no more than to investigate local conditions, has had no difficulty in arriving at the conclusion that many of our wild animals and birds are decreasing in numbers at an astonishingly great rate and that several forms have been practically wiped out of existence.

I do not think that any one section of the country can be accused of more wanton killing than another, for the people of all sections are guilty of carelessness in the matter of game preservation. Every one is familiar with the fact that millions of bison were killed on the plains of the West, but few are cognizant of the fact that the inhabitants of the Southeast had a hand in dealing, what came very near being the death blow to the buffalo tribe. From Carolina on the east to the foothills of the Rockies, the bison was wont to roam; very probably then, the inhabitants of the southeastern country had a hand in the slaughtering. Their herds were estimated to have contained from one hundred and fifty million to four hundred and fifty million. A government census, taken with as much care as was possible, showed that in 1850 the herds numbered about forty million head. By 1883 about the only traces of wild buffaloes in this country were the vast acres of prairies strewn with bones and horn. If the government had employed men to exterminate the bison, they could not have gone at it more thoroughly than the buffalo hunters and Indians did. From 1850 to 1883, a period of thirty-three years, the number slain was more than two hundred and fifty million, or about eight million each year; a record which has few parallels. Ten or twelve years ago there were very few American children who had ever seen a bison. Just a few years ago, we all began to realize that if a single bison was to be left, effective means must be started to put a stop to the indiscriminate slaughter. The few remaining bison, under care and protection have thrived remarkably well, and increased their numbers considerably. The American Bison Society has recently taken the census of the bison, and reports that all told, there are twenty one hundred and eight of them distributed among three government herds, besides various private ones.

On account of the fact that the alligator is a native of the extreme southern part of this country, many people are uninformed as to the rapid decrease which the demand for 'gator skins has made upon the numbers of alligators in Florida and other southern states. Twenty years ago it was a common occurrence to find alligators of great size in many of the streams of North Carolina, South Carolina, Georgia, Mississippi, Florida and Louisiana. In all of these states excepting Florida and Louisiana, the saurian representatives are comparatively scarce. Florida has the greatest number now, not because of any legislation or special effort for their protection, but because the everglades and the mild climate constitute the natural habitat of the alligator. To-day Florida has laws for the protection of the alligator, and is making every effort to have them enforced. They were being killed in such great numbers that, with a few more years of the "pot hunter" and skin collector, the alligator would have been listed among "those which had been." A few figures will suffice to show to what extent the killing of alligators has gone. Between 1880 and 1890, three million eight hundred thousand alligators were killed in Florida alone; and during the year 1908 twenty thousand were killed. In the majority of cases the skin was taken off, and the rest of the body wasted. It was not until 1885 that the demand for the skins was so great, when suddenly fashion decreed that, satchels, pocket books, music rolls, etc., made of alligator skins were just the style; and the above figures show how it affected the number of alligators.

From reports, which represent practically the entire area of the United States, gathered by Dr. Hornaday, of the New York Zoological Garden, one can state without any fear of contradiction that the following mammals, in the wild state, are practically extinct or are rapidly becoming so. Among the ruminants or cud-chewing animals, the bison of course holds first place, with the wapiti or American elk (*Cervus canadensis*), moose (*Alces americana*) and woodland caribou (*Rangifer caribou*) good seconds. Notable among the smaller ruminants are: the Virginia or white tailed deer (*Cariacus virginianus*), mule deer (*Cari-*

acus macrotis), black-tailed deer (*Cariacus columbianus*), prong-horned antelope (*Antilocarpa americana*), Montana goat (*Ovis montana*) and the mountain goat (*Hoploceras montana*). Bears in general are greatly on the decrease, and especially the black bear (*Ursus americanus*) and the California grizzly bear (*Ursus horribilis horriæus*). The carnivores are represented by the puma or mountain lion (*Felis concolor*), jaguar (*Felis onca*), red lynx (*Lynx rufus*), otter (*Lutra canadensis*). The rodents, or gnawing animals, on the whole seem to be on the increase, but the most valuable member of the order to man, the beaver, (*Castor canadensis*) is fast nearing extinction.

Concerning the bears Morse's "Universal Geography" for 1812, states that eight hundred thousand hides were shipped out of the United States every year. If there is such a thing as a bear industry in this country now it is of exceedingly small importance. In 1784, from one city alone, Charleston, S. C., six hundred thousand deer hides were shipped; in 1812 the price paid for a buck was forty cents; in 1878 venison cost three and one fourth cents per pound; in 1908 it took forty cents to buy a pound of venison, just exactly what a whole buck cost in 1812. Evidently there are not as many deer as there used to be.

It is natural, of course, that the wild animals of a country should decrease as the population increases, since an increase in population means that new land must be cleared, and the wild animals living in the region of increase, killed off. In many countries, where the population per square mile is so much greater than it is here, there would be some excuse; but not in America where miles of prairie and mountain are uninhabited. There is not a single region in this country where the majority of species of mammals is not on the decrease.

Bird life, on the whole, has decreased a great deal more than animal life; there are a few regions, though, where birds are increasing in numbers. According to reports received from thirty-six states and territories, Dr. Hornaday is of the opinion that in the last fifteen or twenty years the bird life in the United States has been decreased by 46 per cent. The greatest amount of damage seems to have been done in Florida, where the decrease is 77 per cent. In Indian Territory, the region constituting the eastern portion of what is now the state of Oklahoma, the loss is 75 per cent. From Connecticut a loss of 75 per cent. is also reported. The states having the smallest losses are: Nebraska 10 per cent., Michigan 23 per cent., Colorado 28 per cent. and Massachusetts 27 per cent. In three states, North Carolina, California and Oregon, the balance of bird life has been maintained; that is, the losses in one form of bird life have been made up by increases in other forms. In North Carolina, along the coast region, bird life has suffered great losses, but in the thickly wooded mountainous regions of the western part of the state the birds have greatly increased in numbers. In four states, and to them commendation is due, the number of birds has increased. They are Kansas, Wyoming, Washington and Utah.

What has become of the passenger pigeon (*Ectopistes migratorius*), prairie chicken (*Tympanucus cupido*), the Carolina paroquet (*Conurus carolinensis*); and why are the following so nearly extinct: blue bird (*Sialia sialis*), the white heron (*Ardea candidissima*)? In every case the answer is one or all of the following conditions: indiscriminate hunting, wanton slaughter, and the collection of plumes or of eggs. None of these are natural conditions, and therefore it is not beyond the power of man to better them.

The birds which are affected most by the indiscriminate hunting are the gallinaceous birds, such as the grouse, quail, partridge and turkeys. The wild ducks and shore birds are also considerably affected. The wading birds, among which are the various forms of heron and bittern, have found their worst enemies among the plume collectors, or plume thieves. The men who collect feathers from these birds are not content to pluck the feathers and release the birds, or to confine their depredations to the males; but they kill the female herons, for the plumes and egrets that they furnish, while they are on the nest. It is only during the mating season that the feathers are in a suitable condition for plucking, hence the annual raid made upon the nesting herons.

It seems strange that women, who by nature are supposed to possess so much gentleness and sympathy, and who shrink from anything that savors of cruelty, should be content to adorn their hats with feathers, the procuring of which necessitates so much wanton cruelty and murder. But Dame Fashion has decreed that feathers shall be worn; regardless of how they are secured, they have been worn, and a study of the following figures will give some idea of the effects thereby produced on the colonies of herons and egrets. Within the past twenty years the snowy heron has practically disappeared from China, where it was once so plentiful. Twenty years ago, there was in the region about Charleston, S. C., at least three million of these birds; to-day less than one hundred remain. There is but one small colony of the American egret left in this country, and that one is on the coast of South Carolina. This colony was fired into last year, and again this year, so that now less than twenty birds remain. It will be but a few years, unless some drastic measures are taken, before the history of this bird will be the same as that of the passenger pigeon. Our grandparents tell us of the times when the skies were darkened by the millions of pigeons which were seen in the middle west. Last year a reward of four hundred dollars was offered by a college professor to any one who could furnish accurate proof of a single nesting pair of passenger pigeons. I am of the opinion that no one applied for the reward.

In 1830 the Carolina paroquet was so numerous that it was reported that Audubon killed a half barrel with two shots of a shot gun. In Carolina not a single one remains, and in the wilds of Florida but few can be found.

The prairie chicken was once so abundant, that in Kentucky, where the slave owners fed it to the negroes, they tired of it and begged their masters not to make them eat it. It was commonly known as "nigger bird." To find the prairie chicken now, one must tramp the isolated regions of the west. Even in Indian Territory, a hunter is considered lucky if he even gets a shot at one. I have heard the old settlers say that the prairie chicken was once more abundant than the English sparrow is now.

The game birds are so nearly depleted, that our song birds are being killed off as a result. The quest for game birds having failed, and the desire to "kill something" being still unabated, the "hunter" "takes it out" on the song birds. The blue bird is fast nearing extinction, and the larks and several other songsters are suffering a considerable depletion in numbers.

After reading the above reports of killing and depletion, one is apt to take a pessimistic view of the situation; but thanks to the Audubon Societies, which are pretty well established in every state, the appointment of game wardens, who are beginning to realize that they are personally responsible for the condition of bird and animal life in their region, the issuing of hunting licenses, which necessarily prevents a great many unscrupulous men from hunting, and the widespread interest which is being manifested in the cause, there is no reason why the great decrease should continue.

FOOD PREPARATION AND ITS RELATION TO THE DEVELOPMENT OF EFFICIENT PERSONALITY IN THE HOME[1]

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Introduction

THE main purpose of this paper is to show something of the manner in which woman's work in the home in regulating and arranging the diet of her family may help or hinder their harmonious vital, mental, moral and social development as well as her own, through her ability or inability to make use of the accumulated knowledge of conditions necessary for human welfare.

The purpose also is to show if possible the importance of greater knowledge of what is best for individual welfare on the part of home-makers to whom is intrusted the first and early care of the potential citizen or the social personality with its varied phenomena of vitality, mentality, morality and sociality.

Vitality is fundamental. Without good health we can not expect the highest mental development. Without good health and the vital conditions which produce it we can not expect a high morality. Without good health and the sense of well being which accompanies it, we can not expect a deep sense of sociality or social sympathy.

Two factors operate to produce vitality, *i. e.*, heredity and hygiene. Within the limits of this paper heredity has no place. One phase alone of hygiene will be discussed. The hygienic methods of improving vitality may be classed in three groups—public hygiene or the activities of government, such as general sanitary measures; semi-public hygiene or the activities of the medical profession and institutions such as hospitals; and personal hygiene or the private life of the individual and family.

The subject of personal hygiene has three main divisions: nutrition or suitable foods; environment—air, soil, clothing, dwellings and so on, and activity or the proper balance between work, play and sleep. Still another element in personal hygiene concerns the sex relation. These divisions of the subject of personal hygiene are closely bound together in their importance to human welfare. Yet food is the primary essential of the human organism. Food, then, is the phase of

[1] The writer wishes to express her sense of obligation in the preparation of this paper to the department of sociology and economics and the department of chemistry of the State University of Iowa.

personal hygiene which will be considered in this paper. It will be discussed in its relation to the development of efficient social personality in the home.

We trace first the development of public sentiment in regard to the importance of food suitable to maintain the body in a state of efficiency and health.

Distinct progress in the study of the foods necessary for the body was made when chemists and physiologists began to work hand in hand in their investigations. Liebig (1803–1873) took a step in advance when he declared that protein foods are the source of energy and his statements held sway for many years until they were overthrown by experimental evidence. Fick, who in 1865, made an ascent of the Faulhorn on a diet entirely without protein did much to overthrow Liebig's theory.[2]

Other original investigations followed, for the necessity of experimental evidence had by that time been fully established, until we come to the name of Karl von Voit, who in his studies in metabolism, sought to learn the kinds and quantities of food used by people of different occupations.[3]

Professor Atwater, lately deceased, contributed much by original studies to the subject of diet and nutrition in our own country.[4] But the most scholarly and thorough investigations in this country on the subject of diet in its relation to the actual necessities of the body have been carried on by Dr. Chittenden, professor of physiological chemistry at Yale University and director of the Sheffield Scientific School.[5] In these he has sought to establish by a series of accurate tests of sufficient number to warrant conclusions the minimum requirements of food for the body under certain conditions. He sought to determine the real physiological needs of the body for food in order that energy may be furnished and tissue be built up and replaced.

These data furnished by the chemists and the physiologists concerning the food necessities for individual welfare, the sociologist makes use of in his study of society, for a society can be no more potent than is the personality of the individuals who compose it. Hence, as Professor Giddings says, "The supreme result of efficient social organization and the supreme test of efficiency is the development of the social man."[6]

[2] Gesammelte Schriften von Adolf Fick, "Ueber die Entstehung der Muskelkraft," Band 2.

[3] Von Voit, "Physiologie des Allgemeinen Stoffwechsels und der Ernaehrung."

[4] Atwater, "Foods, Nutritive Value and Cost," "Food and Diet," and others, U. S. Department of Agriculture.

[5] Chittenden, "Physiological Economy in Nutrition," 1904; Chittenden, "The Nutrition of Man," 1907. F. A. Stokes Co.

[6] Giddings, "Inductive Sociology," p. 248.

The phenomena of personality may be divided into four classes: those of vitality, mentality, morality and sociality. According to the author just quoted, "the development of the social personality is measured by the increase of vitality, of sound and high mentality, of morality and of sociality; and by a decrease in the population of the number of the defective, the abnormal, the immoral, and of the desocialized, the deindividualized and the degraded."[7]

The development of vitality is fundamental in harmonious personal growth. From the days of the early Greeks the necessity of a sound body as a pre-requisite of a sound mind has been fully recognized and sought for in accordance with the knowledge available for the subject. The recognition of the connection between moral life and mental life has been somewhat more tardy, as also has been the knowledge of the connection between morality and sociality. Even though Jesus centuries ago declared, "Thou shalt love thy neighbor as thyself," and "He that saveth his life shall lose it," we have been very slow to comprehend the fact that universal brotherhood is indicative of a high type of morality.

However, we have come now to see the fact that sociality rests upon morality, that morality is a differentiated form of mental life, and mental life is conditioned upon physical life while efficient physical life depends primarily upon the food we eat.

Consequently some of the essential studies of the sociologist are food necessities and vital statistics in order that he may understand the possibilities of harmonious development of the social man. This century has been especially rich in studies of this kind, but as long ago as the eighteenth century Adam Smith expounded the advantage to the community of a rising standard of living among laboring classes.[8] In our own century the work of investigation into the standards of living in their relation to social welfare have been undertaken by many individuals and agencies.[9]

The general plan of these investigations has been a study of living conditions as they actually exist among working people, for the most part, because the animating purpose of many of these inquiries has been the desire to improve the condition of the wage earner.

For instance, Mrs. More in the book entitled "Wage Earner's Budgets" gives the results of a personal investigation into the standards and cost of living of two hundred families in two districts in New

[7] *Ibid.*, p. 250.

[8] Adam Smith, "Wealth of Nations," part 1, chapter 8.

[9] The publications of the United States Bureau of Labor, the publications of the Bureaus of Labor of Connecticut and Massachusetts and the publications of the Department of Agriculture; Devine, "Principles of Relief," chapter 3; Bosanquet, "The Standard of Life and other Studies"; Booth, "Life and Labor of People in London"; More, "Wage Earner's Budgets"; Chapin, "The Standard of Living in New York City."

York City. The people represented the leading trades and occupations of city workmen under the usual city conditions. Her conclusion was that a well-nourished family of five needs at least $6 a week for food in households where there is good management, and she says further that what is done with the weekly income and the amount of comfort it will bring depends almost entirely upon the character and ability of the wife.

Professor Chapin in his book entitled "The Standard of Living in New York" presents the schedule of expenses of 391 families on an income ranging from $500 to $1,000 per year. The average expenditure for food was $400 a year per family, but in the families whose income fell below $800 or $900 he found them often under-fed because rent must consume so large a part of their income. Dr. F. P. Underhill in commenting upon the nutrition of people of these incomes says that results show that when less than 22 cents per man a day is spent for food the nourishment derived is insufficient. But he adds that it does not necessarily follow that in every family where 22 cents per man a day is spent the people are well nourished, for not all families spend their money wisely, *i. e.*, one report showing that out of $6.17 a week spent for food $1.83 was spent for beer, wine and pickles.

Dr. Irving Fisher, professor of political science at Yale University, has published the results of two series of investigations as to the effect of diet on endurance. He finds endurance much increased by thorough mastication of food, which unconsciously leads to a much lower protein intake than is usually considered necessary in the so-called dietary standards.[10]

These authorities are mentioned only to show something of the importance which the sociologist to-day is attaching to the phenomena of vitality in the development of efficient social personality.

For the harmonious development of efficient social personality certain general conditions of well-being are essential in which all the members of the community share or may share and, even though these are external to the individuality, they are still necessary to its perfection and happiness. "These external conditions include the security of life and possessions which is maintained by the political system; the liberty and justice which are maintained by the legal system; the material well-being which is created by the economic system; the knowledge and the command over nature which are created by the cultural system. These proximate ends collectively we may call public utilities." [11]

These public utilities are means to an ultimate end. They are of

[10] Fisher, "Influence of Flesh Eating on Endurance," *Yale Medical Journal*, March, 1907; Fisher, "The Effects of Diet on Endurance," *The Transactions of the Connecticut Academy of Arts and Sciences.*

[11] Giddings, "Inductive Sociology," part 4, The Social Welfare.

value only as they serve the individual life, the higher life of moral and intellectual development. By their means is developed a social personality, and this social personality—so far the highest product of evolution—the moral, intellectual and social man is the ultimate end of the social organization.

These proximate ends or public utilities take the form of various organizations in the political, the legal, the economic and cultural systems.

> The supreme test of the efficiency of any social organization is the development of the personality of the social man. If the man himself becomes less social, less rational, less manly; if he falls from the highest type which seeks self-realization through a critical intelligence and emotional self-control to one of these lower types that manifest only the primitive virtues of power; if he becomes unsocial—the social organization whatever its apparent merits, is failing to achieve its supreme object. If, on the contrary, man is becoming ever better as a human being, more rational, more sympathetic, with an ever-broadening consciousness of kind—then whatever its apparent defects, the social organization is sound and efficient.[15]

The home is one of these utilities for the development of the social man. The purpose of the home as a social organization is two-fold—economic and cultural. It is a purposive organization existing for convenience in the consumption of wealth as well as for the cultural purposes of parents and children.

Since the development of social personality through its organizations is the ultimate end of society, the cultural side of the home should perhaps be more emphasized than it is, but as our economic system is organized to-day the economic side of home life receives undue emphasis, owing to the social waste of labor which occurs because each housewife does her own housework, the food preparation, the sewing, the laundry work for her own little group, when by combination there could be a great saving in time and strength and more leisure for real cultural advancement. Society is coming slowly to understand something of this social waste of labor and gradually there have been developing industries which relieve the homes of much sewing, laundry work, and even food preparation.

The home is a human institution, and as such is capable of change and improvement. Other human institutions have come and gone, but the home of to-day in many particulars remains essentially the same as it was when our cave-dwelling ancestors left the woman at home to guard the fire, care for the children and, incidentally, to prepare the food, while they roamed abroad in search of game and new experiences. Those who insist that a woman's place is at home by divine decree need only to study the life of primitive man to find out how very human are some of our domestic customs, for they will then see this distinction, that while nature has specialized woman for child-bearing, it is society

[12] Giddings, ''Inductive Sociology,'' p. 249.

which has specialized her for housework. To be sure, a custom which has continued as long as this one of woman remaining by the fireside must have as its foundation something which is fundamentally right for social development. Yet so many myths have grown up about this custom that we are in danger at times of mistaking these additions for the good of the original idea. Because of these erroneous ideas current, popular opinion is inclined immediately to conclude, if for economic reasons a woman strays from the fireside, that she and her husband are incompatible, or that he is unwilling to support her and that in some way she is neglecting what is popularly supposed to be her divinely appointed mission. Of course such a conclusion is often unjust and not warranted by the facts.

In discussing the subject of the preparation of food, we accept conditions as they are; that woman is specialized by society as the housekeeper and food purveyor to the various groups called families.

In spite of the fact that many of the home industries have developed into world-wide industries there still remains for the housemother much of the food preparation for her family. The necessary meals for one's family are the essential fact which confront each housewife anew each day. No matter what other home activity can be neglected, that one duty of preparing food can not be omitted. How often we hear women make some such remark as this, "I was too sick to do anything else but get barely enough for the family to eat." This shows that every other home duty can in extremity be left undone except that one. Food preparation then is the fundamental duty of the housewife to-day. "A good stomach kept in a healthy condition is the foundation of all true greatness," says Dr. Tyler, professor of biology at Amherst College.

The housemother's first duty then after bearing her family is to provide them with food for their growing needs which shall give them the best endurance for life's conflict. But her responsibility is much greater than this, for closely connected with the necessity for food are the other hygienic necessities for survival—air, water, sunshine, shelter, rest, all in due season; and depending upon these vital necessities are the opportunities for the development of the mental, moral and social personality or the completely social man. Because woman is specialized for home work, these wider responsibilities for individual growth have, in a large measure, become hers also.

The home as a social organization stands as an agent of help or hindrance midway between the well-established theories of the scientists concerning human welfare, on the one hand, and society, on the other, where the finished product of personality asserts itself as a social force. What that force shall be the home can alone determine for by its agency, the theories concerning human welfare must be put into practise and through it as a clearing house must pass in their operation many of the most potent influences which fashion the character of the social personality or the social man.

Naturally then the sociologist in considering the factors which determine social welfare must give especial attention to the home and many phases of its life.

For instance, if the physiological chemists prove that the individual requires for full vital development food of certain quality and quantity to produce from 2,500 to 3,000 calories of energy per day and that individual in his home through the ignorance on the part of those who prepare and serve the food consumes a greater or less amount of innutritious food, just to that degree is the home responsible for the weakening of the vital power of the social personality and since vitality is fundamental, the mentality, the morality and sociality of the individual will in time also suffer.

As custom is at present, we all concede that the home is the center of food supply to the individual and woman's main work in the home for which to-day she is specialized by society is the serving of food to her family which in the majority of instances she has herself prepared, for we are told that only ten per cent. of the women in the country have the luxury of a cook other than themselves. If in fulfilling this humanly appointed mission of food center, any individual or group of individuals in the home in carrying out this plan lose from overwork or under education an opportunity for the harmonious development of the four divisions of social personality—the vital, the mental, the moral and the social, the home standing as it does midway between the knowledge of what is best for human nature in its development and the finished product or the social individual in society—is a hindrance to human progress.

Applying the sociological tests of personality to home life we have a right to ask if our homes, as at present conducted, are making mankind better as human beings, more rational, more sympathetic, with an everbroadening consciousness of kind, and whether there is a decrease in the number of the defective, the abnormal, the unmoral and desocialized. We have a right to go a step further and ask if in the development of this social personality there comes to the individual the satisfaction of its own activity and growth or what Giddings calls "cumulative happiness." That is, in the performance of this specialized industry as homemaker is woman enjoying a sense of satisfaction in her own growth and activity and is she happy in her work? Neither men nor women can have a sense of satisfaction or cumulative happiness in their tasks unless they are fitted for them and do not overwork at them.

We are here according to the modern interpretation of the teachings of Jesus to perform our best service to society and we can do this only by the best individual growth and expression. The right kind of a home can do much to further these results. Warden J. C. Sanders, of the State Penitentiary at Fort Madison, Iowa, said that out of the 455 inmates, very few had had the advantage of a good home.[13]

Although woman is specialized for this important business of home work upon the outcome of which depends first the vital, then the mental, moral and social, welfare of mankind, she receives in but few cases any preparation for her important task. She takes the methods of housework which are traditional in her environment and makes use of them according to her individual training and aptitude. The exceptional woman may use all the data of the scientists in the administration of her home. What she is able to do ought not to be made the measure of what the average woman may be expected to do. The average woman goes blindly on in her specialized work, laboring hard at a task for which she has no aid but home traditions and the columns of the home magazines.

To be sure the home magazines are contributing much toward better conditions of home living, for many women would not know that scientists are at work continually on problems of home betterment were not some of the results of their investigations made available through the medium of the home magazines.

The bulletins of the Department of Agriculture, the farmer's institutes throughout the country, the home economics movement,[14] and many writers—Mrs. Richards, Miss Barrows, Miss Bevier, Mrs. Rorer, Miss Kinne, Mrs. Hill, Miss Farmer, Miss Hunt, Mrs. Lincoln and others—are doing much by a crusade of enlightenment to improve conditions of foods, their preparation and uses in our homes. That is, they are trying to make available for women the knowledge of the scientists, which either is not available for the average woman or else is beyond her mental reach.

For instance, two noteworthy books on the subject of nutrition by Professor Chittenden, of Yale University, have been published in recent years.[15] They are noteworthy because by scientific tests upon different classes of people they show the exact needs of the body for protein, the material for building up and replacing tissue. Consequently some very definite conclusions can be drawn concerning food customs which should be known to every woman and prevail in every household. The essential parts of the books are so plainly and entertainingly written that a woman with at least a high school education could understand them and profit by them. Yet inquiry reveals very few housekeepers who have read them. The reason for this ignorance can be attributed to the fact that as yet woman in her evolution has not reached

[13] An address delivered before the Iowa City High School, December, 1909.

[14] Bevier and Usher, "History of the Household Economics Movement."

[15] Chittenden, "Physiological Economy of Nutrition," Chittenden, "The Nutrition of Man." The F. A. Stokes Company.

the state of mind when she expects to enjoy or understand anything scientific, so she does not seek out that class of reading. Meanwhile, nevertheless, she is in charge of the vital development of the race. A strange inconsistency! Thus we see that in most cases she is not fitted for her work and hence can have no sense of satisfaction in it.

As previously stated the purpose of this paper is to show the connection between woman's work in the home in preparing and serving food for her family and the harmonious development of personality; and also to indicate that as conditions now prevail in society she is unable to make use of the accumulated knowledge of scientists as to what is best for human welfare.

With this purpose before us we need to keep in mind the image of the home as an intermediate agent between the scientific knowledge of what is best for human development, on the one hand, and on the other the finished product of personality as we find it in society. Since the home stands as the connecting link between these two—the knowledge and the result, it must of necessity help or hinder the harmonious development of the social personality or the individual in his relations to his fellow men. Hence anything which will improve home conditions is of great importance to society in its attempts at individual and general progress.

In the face of these responsibilities which center around the home and the housemother in the vital, mental, moral and social care of her family, because she is specialized by society for home work, let us consider some of the results in the working out of this system.

Statistics tell us that under the present home system one fourth of all deaths for the United States during the year 1908 were of children under five years of age.[16] The infant mortality of England was higher for the three years 1896–1900 than for 1861–65.[17] Of the total deaths in Iowa in August, 1910, about one fifth were under one year of age and of these over 80 per cent. were from cholera infantum, a disease largely preventable through hygienic measures.[18]

It is stated of all diseases of infancy between the ages of 2 and 6 sixty-seven per cent. may be prevented on the basis of our present knowledge of sanitary measures, were they widely used.[19]

Statistics tell us that under the present home system, the prevalence of disease greatly impairs efficiency.

In the United States, 500,000 people are constantly ill from tuberculosis alone, which is in a large measure a preventable disease in

[16] "Mortality Statistics," 1908, p. 8, Special Census Report, Department of Commerce and Labor.

[17] *Ibid.*, p. 9.

[18] Rockwood, POPULAR SCIENCE MONTHLY, March, 1911.

[19] Irving Fisher, "Bulletin of the Committee of One Hundred on National Health."

the homes where it is understood and the necessary diet and food are provided.[20]

The minor ailments, such as colds and sore throats, cause even well men to lose at least five days a year from their work.[21] Yet investigation and research are showing that these minor ailments can be controlled in a large measure by diet.[22] Professor Fisher says that he knows scores of cases in which the tendency to take cold has been almost completely overcome by diet. Such being the case it will be necessary for those who prepare and serve the food to be cognizant of what kind of food the body requires for its highest efficiency, and since as society is now organized, the preparation of food is woman's work, it must be possible for women to know in some way the latest results of scientific research in foods and general hygiene in order to prevent disease.

Statistics tell us that misery, which represents maladjustment to environment, is frequent in rural as well as in city life. "Perfect health, full physical vigor and overflowing animal spirits are much more rare among dependent classes than moral virtues. The prevalence of ill health is due in large part of course to ignorance and the continued neglect of the elementary rules of personal hygiene." [23]

It is a noteworthy fact that after the destruction of the homes by the San Francisco earthquake the health of the community as a whole improved, due no doubt to the plain, substantial food, the outdoor life and the military system of sanitation, where before people had been living in homes in accordance with their individual ignorance. Professor Devine states also that there is great need of medical knowledge in our homes to overcome the ravages of such diseases as the minor maladies of rheumatism and colds.[24] This puts the responsibility of human health on the home and the woman in the home who has charge of the preparation of food, the vital welfare of mankind and hence the other dependent phenomena of personality.

Professor Devine says, in speaking of the waste of infant life, that in England 10 per cent. of the babies of aristocratic families die in the first year, 21 per cent. of the middle class, and 32 per cent. of the laboring class, which facts show that the ignorance of the proper care of infant life is not altogether due to poverty.[25]

Many charity workers report that the "unpreparedness of the wife and mother" to make a home is often a cause of misery, because through ignorance disease comes and disability, with much resultant suffering and want. In these homes where the unprepared mothers try often-

[20] *Ibid.*, p. 3.

[21] *Ibid.*, p. 39.

[22] *Ibid.*, p. 40.

[23] Devine, "Misery and its Causes," p. 74.

[24] *Ibid.*, p. 84.

[25] *Survey*, December 4, 1909.

times so nobly to adjust the personalities of themselves and their families to adverse conditions, Professor Devine says, "We find the beginnings of those tendencies which often lead to suicide or crime, to disabling disease or helpfulness." In this same connection of the preparation of home makers for adapting themselves and their families to their environment, charity workers agree that among working people the women who have been in domestic service are much better able to manage on their income than those who have spent their girlhood in factories.[26] Intemperance, which is known by all charity workers to be a prolific cause of crime, is often excused in its first manifestations as resulting from innutritious food. In families where the wages would be sufficient to supply nutritious food, the homemakers do not know how to buy or to prepare it. Hence previous domestic training is of great value.

This "unpreparedness" of women in our homes is not confined alone to a knowledge of foods. Because woman is specialized by society for housework, and the care of children, the general responsibility for the health of her family is hers also. But so often through ignorance she is not equal to this responsibility. For instance, statistics and the reports of the various state charitable institutions show that a large per cent. of blindness among children is due to diseased conditions which might be remedied by intelligent care at birth,[27] or might have been prevented years before by a proper knowledge of sex hygiene.

Intermarrying is also given by experts as a cause of physical degeneracy such as deaf mutism. Both of these social errors might be diminished by greater knowledge on the part of the guardians of the homes of the vital necessities of the race in the matter of sex and reproduction. The economic necessity which presses so hard to-day upon the man as bread-winner of the family lays all the more responsibility upon the woman in the home not only as in the first essential of food, but in all hygienic matters which pertain to vital efficiency.

Statistics tell us that with the present home system divorce is increasing much faster than the population. Divorce was about three times greater in 1905 than in 1870.[28]

The special census report of the Department of Commerce and Labor shows that the most important ground for divorce is desertion and of the divorces granted to the husband nearly one half had desertions as their cause. That is, one half of the husbands who sued for divorce had for a cause the desertion of the wives. It would look from this fact as though women are growing weary of home conditions.

We have then the fact that with our present system of homes, one

[26] More, "Wage Earner's Budgets."

[27] See report for 1908 Illinois Institution for the Blind.

[28] "Marriage and Divorce," p. 11, Special Census Report, Department of Commerce and Labor.

fourth of all deaths are of children under five—those who are entirely dependent on the home whose diseases in 67 per cent. of the cases could be prevented by proper diet and care. We have the fact that 500,000 people in the United States are ill of tuberculosis and that such prevalent diseases can, in many cases, be cured by diet and fresh air. We have the fact that as estimated even well people lose at least five days a year from colds and minor ailments which might have been largely prevented by a proper diet. We have the fact that one half of the women who are divorced by their husbands desert home voluntarily. We have the fact that many charity workers give as their testimony that much social misery is caused by the "unpreparedness" of the homemakers. We have statistics to show the great waste of infant life in mansion as well as in humbler home. We have the statement of Professor Devine, the well-known charity expert, that in many homes we find the beginnings of tendencies which often lead to crime and disabling disease. We have the statements that innutritious food is a prolific cause of intemperance, which of itself leads to crime. We have the facts that much blindness and physical degeneracy might be prevented by a proper knowledge made available to the masses through the housemother in the home.

In the face of all these facts it would certainly appear that woman, who is the guardian of the home, is either ignorant of the proper consumption of wealth in the home in serving human welfare or else she is remiss in her duty. It is safe to say that not all women would be consciously negligent or remiss in their life's work, so the natural conclusion is that woman for the most part is ignorant of many of the essentials of the great mission assigned her. This ignorance is not strange, since in our educational system she receives slight preparation for this her real life's work. As has been said before, all the aid she has are home traditions and the home magazine, and in the majority of instances she is ignorant of the noteworthy investigations along her own line of work.

Ignorance of right living being so apparent in the face of these statistics, it has thus been shown how woman's specialized work in the home in charge of the food supply can hinder the harmonious development of efficient personality through her inability primarily to maintain and increase the vitality of those intrusted to her.

On the other hand, in order to fulfill the further purpose of this paper and to show something of the manner in which woman's work in the home in providing food for her family may help their harmonious mental, moral and social development, and to show if possible the importance of greater knowledge of what is best for individual welfare on the part of the homemakers, three divisions of the subject are made.

1. Since by results woman is shown so ignorant of proper methods of nutrition which will prevent disease and death, methods of improv-

ing the commissary departments of our homes are suggested by means of education.

2. Suggestions are made of a practical and natural method of developing the efficient social personality of the child in the home, and an attempt is made to show how a woman following out the industry for which mankind has specialized her can develop her own social personality.

3. At least one preventative of divorce and unhappy home life is suggested.

1. The Need of Educated Homemakers

Let us bear in mind the fact stated before that the home and its caretakers stand as a connecting link between the knowledge of what is best for the individual and the finished product of personality as we find it in society. Or, in other words, the function of the home and of those who minister there is the adjustment of the individual to society through the utilities of the home which are both economic and cultural. Certainly such important work should require some special training. While primarily woman's work is that of dietitian in the home, she must not specialize in this capacity at the sacrifice of her effectiveness as a teacher or the cultural size of home life will suffer. Neither must her training as a dietician and a teacher exclude the training necessary as a financier and as an employer of labor in a broad sense, for the home is in direct touch with the labor problem on all sides. The liveliest imagination and inventive genius she will need also to develop to enable her to meet with discrimination and equanimity the daily complex problems of home life.

It is to be hoped that as yet woman's education is in a transitional stage. The last half century has been given up to proving that women can learn the same lessons as men if they wish to do so. It is very desirable that the next half century may mark a much greater triumph in woman's education by making plain and popular the fact that although she can learn the same lessons as a man she, as a woman, has more important ones to learn of an entirely different nature, bearing on her profession of home making.

No man without special training is likely to be employed as consulting engineer on so important an enterprise as the Panama Canal, yet women the country over are intrusted with the vital, the mental, the moral and social welfare of the individuals who make up the state, without any preparation whatever beyond an inheritance of tradition and such additional information as can be gained from home magazines or such other literature as their minds are able to grasp.

There is a sentiment current in respect to woman's higher education that if she is given culture studies, ability will in some way come to her for her life's work. Culture studies are good, but they are only part of the preparation needed by her. She needs for her life's work much more preparation than is ordinarily included under the subject of domestic science in order that she may be competent to develop the personalities of her family in every way. A suitable course for her in order to be of wide value should be a bringing together of all the work of her college days in its bearing upon individual adjustment to society through the medium of the home. The studies of literature, art, music, psychology, pedagogy, child study, emergency nursing, chemistry, physiology, biology, bacteriology, botany, sociology, *in their bearing upon home life,* will all be necessary for this ideally equipped homemaker. She needs, in other words, to be taught how to control her environment by making use of the knowledge which is available for race progress.

It is not going too far for the state through its educational institutions to require that each woman graduate who goes out from their walls shall be thus equipped for the work which is of greatest value to the state through the home. For instance, the state of Iowa now requires a course in pedagogy extending through much of two years for those who wish to have a state certificate to teach. Iowa might well go much farther and require that each woman who graduates from her university shall be prepared by suitable studies for the position of homemaker which sooner or later she may assume. Iowa is a progressive state in many respects. She is the first to put her educational institutions under a coordinating board. This board has within its power to take a distinct step in advance by enabling the university to offer studies which are especially suited for developing educated women as homemakers and as guardians of efficient social personality.

Most state agricultural colleges and state normal colleges have schools of domestic science to train teachers. The state universities as the crown of the educational system need training schools for wives and mothers, with all the advantages which higher education can give. This training must be of the very highest grade and no expense should be spared to make and keep it thus, so that every woman who goes forth from their halls shall be a center of light in the broadest way on the subjects of the hygiene of environment, of nutrition and of activity. If these conditions can be made to prevail in all our educational institutions, it is safe to say that the coming century will mark great vital, mental, moral and social advancement of the human race. Statistics tell us that at the present time 74,908[29] women are enrolled in the higher institutions of learning in this country. If each of these 75,000 college women and all who succeed them could go forth from their college life thoroughly prepared for their duties as women a great increase in individual and national efficiency might be expected.

The fact that many women say they "hate house work" does not lessen their responsibility for doing it well since they undertake to do it.

[29] Wm. G. Curtis, "Ages of Universities," *Record Herald,* April 15, 1910.

A proper education in the fundamentals, the purposes, the methods and the results of home work would no doubt go far to lessen the dislike for that form of labor. The difficulty with the "Man With a Hoe" and the woman with a broom is often the mere fact that they see no connection between present effort and remote results, and thus have no sense of satisfaction or happiness in their work.

Until by a process of evolution some plan of farther combination or socialization of home industries is worked out, in order to raise the standard of home industries it is necessary to take immediate steps to improve conditions in our homes. A wholesale campaign of education of our girls, beginning with the grade schools and extending through our colleges, is the most hopeful means available for improving our homes in their work of developing and maintaining individual and social welfare through the proper adjustment of the individual to society.

2. Home Methods of Developing Personality

One of the difficulties of our educational system to-day is that educated women seem to feel that when they assume the responsibilities of home work they have been made to surrender to disuse whatever mentality they possess. Indeed, one very capable woman said to the writer soon after her marriage, when she was wrestling with the difficulties of domestic management, "Do you not feel your mind becoming atrophied with all this petty round of duties?" In order to be loyal to our little home nest, I replied, "No indeed, I find that my domestic science takes as much mentality as my political science did." I have been trying ever since to live up to that remark, and I have found that the homemaker by following out her path of duty can have an opportunity for mental, moral and social development in proportion to her desire for growth.

The whole world of science centers around the daily work of preparing food. The housewife who wishes mental expansion in this line can begin by perusing the numerous food bulletins of the Department of Agriculture which are provided free. She can hang her kitchen walls with the food charts furnished by the Department of Agriculture for a consideration and learn while at her work the relative values of foods. This knowledge will prepare her to be interested in the many food experiments of the large experiment stations, and while following them through the publications she can add to them by carefully kept records of similar experiments in her own home, and if she is of a literary turn of mind she will find a ready sale for such articles as she chooses to write on the subject. Personal experience has verified this in the study of the food requirements of growing children.[30]

Her interest in her own growing family can lead her to a study of the development of the family, primitive culture and the development

[30] E. W. and L. C. Rockwood, *Science*, XXXII., p. 351.

of the home and the different phases of what Baldwin calls "the dialectic of personal growth" which occurs in the socialization of each of her children. While she is increasing her own stock of information in this way she will find that she is becoming a much more interesting companion for her children and is able to show them their real place and share in the world's work. In this way she can exert a much wider influence over them than by merely providing for their physical wants.

We are accustomed to say that the human necessities are food, clothing and shelter. We might better say that the human necessities are food, clothing, shelter and thoughts, for the mind needs food as well as the body. A growing child can get along without clothes and shelter if the climate is not too severe, but he must have physical food and mental food or else fail in human evolution. The mother makes a dire mistake if she ministers to the physical needs alone, and neglects the mental, moral and social personality of her child. While walking along the path of her own home industry, she will find that she can interest her children in world-wide problems, for children can become interested in almost any subject.

For instance, the boys I know best became very much interested in primitive culture, primitive man and his investigations growing out of their interest in the domestic use of fire. They read with delight "The Story of Ab" and parts of Jack London's "Before Adam." They constantly asked for anything new on these subjects. One day their mother heard some one say that when a man is drowned he is always found with his arms up over his head and that this posture is probably a survival of his tree-dwelling days. A few days afterward, the twelve-year-old boy came into the house much the worse for wear, muddy, torn and bruised, but with face radiant. To his mother's query concerning the cause of his condition he exclaimed, "I fell through a manger in an old barn, I suppose I am hurt. I don't know. I didn't have time to think, for when I came down I found my arms were up over my head and I am sure my ancestors must have been tree men."

That mother by following along the path of her own duty had succeeded unconsciously in teaching her boy the power of mind over matter or the uplifting power of an idea and of awakening in him an interest in historical and sociological study.

Lessons in wider social service and morality can be taught just from the necessity of the housemother's preparing food, for children can early be taught to share good things with others less fortunate and they can cultivate the spirit of hospitality.

However, it is quite difficult much of the time for the mother in the home to cultivate a wide feeling of brotherhood in her children, just because the mad scramble toward self preservation which the household duties of to-day entail upon her, if she has no outside help, is apt to develop in the whole family an unwholesome egoism.

A small minority of the women of the country have house servants. This fact means then that the majority of the women, if they do their housework well in all its departments, must have a proper idea of values in order to enable them to do the essentials and leave the non-essentials. However, in order to be an ideal housewife and mother in her work of developing the personality of her family, each woman will need all the aid which education and training can give her as well as a still farther combination of some home industries in order to enable her to have time for the real essentials of abundant life.

Enough has been said to indicate how a woman in following out the profession for which mankind has specialized her in the home can develop her personality in its various lines and that of her children at the same time, if she has wisdom and training. Upon what high ideals she is weaving into their lives depends the steady advancement of the human race.

The supreme moments of the homemaker's life are those when she realizes that her family turn to her for counsel in the deeper questions of life as well as for the fundamental physical needs of food, clothing and shelter.

Not long ago several hundred club women in one of the eastern states were asked to reply to this question, "Who is the greatest woman in history?" Numerous replies were received and a great many women known to history were named. The prize was given to this answer: "The wife of a man of moderate means who does her own cooking, washing and ironing, brings up a large family of boys and girls to be useful members of society, and finds time for her own intellectual and moral improvement—she is the greatest woman in history."

Alarmists tell us sometimes that the home is disintegrating, that with the invasion of some women into industry and the indifference of others in regard to their home responsibilities, the death knell of the home is sounded. However, as long as the home can contribute anything to the development of personality and race progress, it will remain. With advancing education and civilization, no doubt, several of the functions which we now consider necessary will pass from the home, but our homes as the sanctuary of family life are not in danger of disintegration. While there are father-love and mother-love and dependent childhood there will be homes where the physical, the mental, the moral and the social personality can be developed.

If any one thinks the home can go and institutions can take the place of home life with its many activities in the development of personality, let him read this statement, which is typical of many other authorities on the subject from Mr. R. R. Reeder, for many years superintendent of the New York Orphan Asylum.

> The most important part of the social and moral education of a child normally situated is the conversation especially the table talk with the parents. It is here the children get their views of life before starting out into the larger world they must enter—I must add also just here that the most valuable part of the child's industrial training is his cooperation with parents either by labor or by economic use of their means in maintaining and promoting the interests of the home.[31]

As long, then, as there is a demand for the influences of home life, the home in some form will continue, for we have not yet outlived the beneficent influences of home life, even though we have outlived some of its former customs.

3. A Prevention for Divorce

The subject of divorce is one which much concerns the sociologists and theologians to-day because of its demoralizing influence on the development of efficient personality in the family.

Satistics tell us that during the period from 1900–1905, while the population increased 8.7 per cent., divorces increased 22.1 per cent.[32]

It is not the purpose of this paper to enter upon a discussion of divorce except in so far as it is affected by woman's specialized industry in the home of food preparation and resulting necessities. Statistics are wanting on the subject, because as yet the sociologist has not known how to collect them, but a careful observation extending over fifteen years has led to the conclusion that many of our archaic home conditions are prolific causes of discontent and incompatibility. For one thing a woman who must work sixteen hours a day at unspecialized industry with the attendant fatigue, is unable to compete in charm oftentimes with the leisure parasitic class whose lives are devoted to pleasing men. Such overworked women are too tired to be interested in men's affairs or themselves interesting. Oftentimes because of this lack of leisure the discordant note is struck which later grows into utter lack of harmony.

Sometimes too the duties of married life are so taxing in the early years when the children are small that women, because of their excess of physical work, begin to feel a mental deterioration, and this consciousness of a lack of growth or of cumulative happiness often is the pathway leading to the divorce court. On the other hand, if a woman by means of any previous training is enabled to keep in touch with the mental life of her family as well as the physical life, she has in her work of motherhood found the one thing in life worth while, and in her work then she can feel a sense of satisfaction in her own growth and activity or "cumulative happiness," for she has found her share of the world's work. All the learning she can acquire will be none too

[31] "Charities," Vol. 11, 1908, p. 151.

[32] "Marriage and Divorce," Special Census Report, Department of Commerce and Labor, 1909.

great for her task, for the growing child is a many-sided personality interested in many things and the mother being most closely associated with him is naturally his teacher and guide, and must know something of many things in order to come into sympathetic touch with his busy brain.

We know, however, that divorce frequently comes in families where women are really idlers in the economic field, who have no responsibility beyond a good time and to be supported by their husbands. In these cases idleness, discontent, desertion and divorce are the result. A socialization of industry would be a good thing for this type of women by compelling them to have some definite share in the social service, for we all know that there is no greater cure for the blues and discontent than rational activity. By the socialization of domestic industry, if it could be brought about, the monotony of isolated home labor would be removed.

The difficulty with the woman who has too much work to do in the home and the woman who has not enough work to do is that they lack expressional freedom, partly from overfatigue and partly from lack of knowledge of the happiest means of self expression. It is a noteworthy fact that Massachusetts, where women are so largely employed in industry, stands forty-first in the matter of divorce, while Washington, where women are not much employed in industry outside the home, stands first, having produced 513 divorces to every 100,000 married couples. All this may go to show that women who are busy in social industry have little time to dwell upon grievances.

A good broadening course in our schools and colleges with a proper presentation of the duties of adult life would do much to lessen divorce, because after all the home is just what men and women make of it as a public utility in the development of efficient personality. Such a course would serve also to establish a tradition in favor of the home-maker and prevent in some degree the rush of women into outside industries which to many now appear attractive.

One of the difficulties with our educational system to-day from the kindergarten upward is that it seeks to make hard things easy, from the learning of the multiplication table to easy helps for Latin and kindred subjects. The only really satisfactory way of mastering the multiplication table is by definitely learning it. All through our educational system this spirit of helping children to avoid the hard things which require persistence and application is shown in our home life when neither men nor women are able to endure the hardships and unpleasant factors which do come up in every home at some time.

Instead of facing these difficult problems and bringing to bear upon them a rational mentality which will restore order from chaos and strengthen the bond of helpfulness between husband and wife, the husband and wife brought up by our educational system to look for easy things, drift from not knowing how to assume responsibility in the home to avoiding it altogether by means of the divorce court.

There are no statistics to prove the statement, yet careful observation in a good many cases has shown that a cheerful common sense and ability to turn defeat into victory through perseverance would have kept many homes intact to-day.

And so, our educational system seems wrong when it permits our boys and girls to grow up looking only for easy places. Too many girls look forward to matrimony as a life of surcease from the disagreeable surroundings before marriage.

In consequence when the water pipes burst and the furnace grate falls out and the refrigerator springs a leak and the baby is teething and fretful and the meals must be prepared and the husband, owing to a belated breakfast, has not had time to be as affectionate as usual in his farewells as he ran for his car—when such a combination as this happens, as we housekeepers all know it can do—unless we are trained to listen for the eternal harmonies behind some of the discords of life, we are apt to grow discontented in home life because of our own inability to make a success of it and to bring to ourselves "cumulative happiness."

However, if we do have a sufficiently high ideal of our mission as homemakers and the spirit and necessary training to inform our task, we can set to work on our domestic problem with a cheerful courage, for we know that ice can be thawed and leaks mended, furnace grates repaired, cross, fretful babies can become the joy and light of a whole household, and belated husbands if only given a chance can more than atone for their seeming indifference.

The explanations just given are presented in order to make the point that an intelligent appreciation on the part of our girls of the responsibilities of home life and skilled knowledge on their part of how to perform their tasks will do much to prevent discontent in the home and desertion from it when unpleasant combinations really arise.

The natural conclusion from this fact is that our educational system should provide some way of showing every girl that she must expect serious conditions in dealing with the serious problems of life and that she must have some training for her fundamental task of developing vital personality with its resultant mental, moral and social responsibilities. Otherwise our whole industrial system must change so that domestic industries can become socialized and women do their share, specializing for home work according to inclination. But in either case for human evolution we must have trained guardians of the personality, whether they be natural mothers or selected ones.

This is not an easy program which is outlined for womankind, but it can be made a very efficient one in race development. The quickest way to get desirable results is by wide-spread education, rather than by waiting for any possible change in our industrial system.

With an increased training in efficiency of women for home industry there can be expected less discontent with unsatisfactory conditions and consequently less divorce. The unity of the home will thus be strengthened and there will result improved conditions for the development of efficient personality.

Thus could be brought together through the necessity of woman's preparing food in the home the best demonstrated forces for the development of efficient social personality.

With a trained womanhood alert for defects and excellencies in home conditions, the home as a social organization in its aid to personality would in time be much improved, for evolution would demand new conditions and the women as guardians of the home through their training would be responsive to these demands.

That there is an awakened public conscience on the subject of the dissemination of knowledge concerning public health is shown by the facts that there is a movement on foot to take from the various government bureaus those departments which relate especially to public health and combine them in one health department, and a petition has been prepared for congress asking that it provide by its bulletins help for women in the homes similar to that which is furnished farmers by the Department of Agriculture.

All these are good signs of progress, but, after all, since now and for many years to come society is going to demand that woman be the guardian of the home, that she prepare the food, that she shall be her children's closest teacher and friend, the most efficient manner of developing personality in the home will be by suitable education of the growing girl and the young woman in preparation for her life's work.

Conclusions

The supreme test of our home organization according to the facts which have been stated is whether or not through its means there is an increase in vitality, mentality, morality and sociality and a decrease in the number of abnormal, unmoral, desocialized and degraded.

Some statistics tell us that when women remain in the home rather than go into outside industry, that there is greater steadiness and industry on the part of the husband, owing supposedly to more hygienic home conditions.

Statistics tell us also that longevity is increasing, that it has increased five years since 1855.

Then our homes, standing as they do as the connecting link between the knowledge of what is best for the race and the finished product in society, are doing a great work.

However, on the other hand, statistics as quoted above tell us that the death rate of infants is abnormally high, that preventable diseases are excessively prevalent, that divorces are too frequent, and that the "unpreparedness of women" is responsible for sickness, disability, degeneracy and resulting misery or maladjustment to society, and that if only the knowledge available for preventing disease could be disseminated and utilized, longevity would be much increased.

These facts show that while the mother in the home by the preparation of food and resulting responsibilities is doing much for race betterment, there is imperative need for greater ability in some way to enable woman to make use of the results of scientific research, in order that there may be in the human race "an increase of vitality, of sound and high mentality, and of sociality."

A practical service of the sociologist is to reveal points at which educational work will tell for race advancement; so an attempt has been made to show that a changed system of education for girls can do much toward a harmonious development of personality, and that this preparation of food for which society has specialized womankind may be fundamentally helpful in individual growth if the housemother can do what she does intelligently and does not do so much of it that she can have no sense of success in it.

The state assumes the right to say what training in its institutions people shall have who intend to practise medicine or dentistry, or law or to teach children in public schools. It ought to assert some control over the training of people who are to be in charge of the consumption of all wealth and of child culture in the home. The ordinary college education is not enough, for many unsuccessful homemakers have that.

The training for educated homemakers should include a thorough knowledge of the subject of personal hygiene with its three divisions: (1) nutrition, or a knowledge of the food requirements of mankind and the best way to provide for them; (2) environment, or a knowledge of air, soil, dwellings, clothing; (3) activity or a knowledge of the correct proportion between exercise and rest.

Each one of these divisions includes many departments of learning. To these subjects should be added a thorough knowledge of sex hygiene. With a knowledge of all these subjects should go an attitude of mind which is able to develop powers equal to one's tasks.

THE CONSTITUTIONAL CONSERVATISM OF WOMEN

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IN the course of his essay on emancipation—black and white—written at the close of our civil war, Huxley says that with few exceptions the ideal of womanhood in his generation seemed to oscillate between Clärchen, on the one hand, and Beatrice, on the other. That women are intended neither as guides nor as playthings, but as comrades, fellows and equals, in so far as nature herself raises no bar to equality, at that time had not penetrated the minds of those entrusted with the education of girls. But even the densest media are ultimately permeable, and if we can now point with pride to certain accomplished results, it is because the underlying principles have not only been discovered and understood, but practically applied.

At heart these principles are biological, and the success which has attended their application depends on the fact that women share the senses, perceptions, feelings, emotions and reasoning powers of men, and that the average woman deviates less in these respects from the standard of men, than one brother differs from another. But problems are fatefully linked together, and the answer to one is invariably the herald of others. If the education of women has demonstrated both its feasibility and value, the inevitable next question clamors for solution no less insistently than its progenitor. Now that she is educated, what shall we do with her? Perhaps at this point biology can aid us anew and point the moral to a tale which itself may have proceeded no farther than the opening paragraph.

Whoever has sufficient temerity to read all that has been written on the subject of sex in twenty years, is likely, sooner or later, to revert with a sense of freedom to Geddes and Thompson's splendid work,[1] there to rejoice in a view by no means out of harmony with recent results, and so comprehensive that the truth, though still "in block," lies well within the field of vision.

Beginning with the simplest cases, and ending with the almost hopelessly complex sexual life of man himself, these writers reduce all to elementary terms in physiology, and find the fundamental difference between the sexes in the essentially disruptive diathesis of the male, and the essentially constructive diathesis of the female.

[1] Patrick Geddes and J. Arthur Thompson, "The Evolution of Sex," American edition published by Scribners.

These abstract characterizations, however, can convey little meaning without the evidence on which they rest. What does "constitutionally disruptive" imply, and what "constitutionally synthetic"? It is a far cry from humanity to the cochineal insect, yet this may serve as our point of departure. The well-known dye derived from this species is elaborated entirely by the females, who store it in huge quantities and as a result are condemned to a life of quietude on the sustaining cactus. The males, on the other hand, are small in size, quick in movement and short-lived.

This division of labor, though somewhat pronounced, is not a biological freak; it can be matched, more or less closely, many times, not only among insects, but among other animals, both lower and higher in the scale of being. Sexual differentiation among birds and mammals, however, manifests itself not by some one glaring difference of habit, but usually in smaller ways; in ourselves, in the sudden and strenuous outbursts of activity, characteristic of men, especially of young men, boys and barbarians, and in the patient, long-continued, and less violent expenditure of energy ordinarily seen in women.

Of course these distinctions are broad and have no bearing on individual cases. They serve rather as convenient, though well-founded rubrics under which to array the leading characteristics of the two temperaments whose existence affects our daily conduct in a hundred ways. Nor is this dealing with averages, whose constituent items merge unrecognizably in the multitude, disadvantageous, for in matters that seem to involve a whole kind, evidence from this or that individual affects the general result no more than my tall friend makes the average height of men other than it is.

While the males and females of fishes, reptiles and amphibians, follow the rule of the cochineal insect, exactly the reverse is true of birds and mammals, for among these the males are practically always the larger. In reality, however, maleness and femaleness are fundamentally unaltered throughout the living world, and the apparently contradictory evidence from the higher forms of life is traceable to their peculiar habits of reproduction.

Most important of all in this connection is brooding, for it throws light, from two angles at least, on the physical superiority of the male sex. Maternity, whether in birds or mammals, demands tremendous sacrifices—in fact is the very thing responsible for their higher development. Moreover, these sacrifices are not laid down in one lump sum, but bit by bit, and it may take years before all the premiums needed to insure a new life completely have been paid up.

Greater, albeit subtler, effects than come from these drains, are traceable to the inevitable stagnation of females incapacitated by incubation or pregnancy, for the quietude necessitated by these states is offset by stress in the male. Food and protection must be furnished for two instead of one, and at times for more than two. It is because effectiveness during these critical periods is racially essential, that the males are larger, stronger and in general more pugnacious.

Our point of vantage includes also those flagrant expressions of masculinity, known as the secondary sex characters: among birds, the resplendent plumage of the cock, the comb and wattles; among mammals, manes, horns and scent glands; in man, the beard and deep voice. All these are the outward signs of maleness, for they come and go with the sexual life, and their development may be stunted or prevented by operation. Gelded stags never renew their antlers; sheep, oxen and antelopes grow inferior horns; whereas the preservation of valuable soprano voices in men is assured by the same means.

These effects are due to the absence of certain chemicals normally emanating from the male sex glands. Analogous results may follow in operated females, but usually most illuminating complications set in, for the female not only has distinctive characters of her own, but is largely dependent on the suppression of those belonging to the male. The functional derangements often associated with old age involve changes in the chemical output of the essential organs, and explain, not only the crowing hen in the barn-yard, but the greater resemblance of the sexes in senescence than in middle life.

All this is reducible to a chemical basis, certain substances being necessary for the development and persistence of the characters that stamp the male; others being essential not only for the positive traits of the female, but also to insure her freedom from male tincture. From the standpoint of the male, the female is an instance of arrested development, a conclusion bodily transferable to other attributes, for except in matters peculiarly her own the female is surpassed in amplitude by the male. Physiologically he cuts a wider swathe, and this inevitably involves greater variability. Accordingly we find that not only as an animal, but as a thinking being, man presents more departures from mediocrity than woman. On this point history testifies with her right hand up, for numerically and as individuals, men have always excelled, not only in knowledge and art, but also as sinners and fools.

We may blame the social heritage of women for the supremacy of men, but heritage and supremacy alike have their head-waters in the greater variability of the male sex, for variability means special fitness for advancement. Departure from traditions has ever been the first step of progress, and it is to our variants, our gifted men and geniuses, that we owe railroads, wireless telegraphy and airships; it is to them also that we are indebted for our greater stories, plays and poems, and even for our deepest thoughts. This type of man startles us by his originality, and brings into the world things before unknown.

The history of civilization, however, is only half written when all the departures from mediocrity have been listed and analyzed, for tradition clings inevitably to the coat-tails of departure, and holds it close to solid ground. If the greater variability of men is the gift that fits them to explore new fields, nothing is more certain than that the less erratic organization, both physical and mental, of women, fits them for administration, conservatism, tradition and culture.[2]

These special aptitudes are sexual differentiations no less truly than bristling beards and flowing tresses, and under modern conditions, infinitely more important. Nothing, however, could be more fatal to any cause, involving either men or women, than failure to recognize that the natural endowments of the sexes are complementary, racially essential and, fortunately, bred in the bone.

It is at bottom, failure to recognize this that has given rise to the current opinion that the emancipation of women through suffrage would destroy maternity. This, if it means anything at all, means that it will destroy sex. Those who have fears in this direction will do well to remember that the sex of woman is no less solidly grounded than the sex of man, and that both are infinitely older than our civilization whose earliest date is only this morning in the complete history of the race. We are the descendants of untold generations before Adam and Eve, and sex is more strongly inbred than the ten fingers.

Biology knows only racial justice, but racial justice in the long run will require suffrage for women, because they are constitutionally fitted for the exercise of the conservative influences of which, as a body politic, we stand so much in need. That the enlightened woman will wield her power without blocking progress, and, within human limits, for the prevention of errors, and the conservation of things worth while, follows both from her organization and her training. Society to-day is losing the services of a specialist in these matters, one too, not only endowed by nature but strengthened by education. When once this becomes clear, shall we continue to doubt her ability to face the waves of jingoism that periodically unsettle our markets and industries, distort the prices of living, and even carry us into trivial yet costly war?

[2] W. K. Brooks, "Woman from the Standpoint of a Naturalist," *The Forum*, Vol. 22.

FLOATING ISLANDS

By SIDNEY POWERS, B.A.
WILLIAMS COLLEGE

IF one should see in a story the statement that a floating island 100 feet square, upon which were growing trees thirty feet in height, was used by the hero as a place of refuge, and that the island traveled 1,000 miles out to sea, he would probably accuse the author of an abuse of the imagination. But such an island—without the hero—was seen off the coast of North America and is known to have traveled at least 1,000 miles. Floating islands also occasionally occur in the lakes of some of our northern states. It is the purpose of this article to point out the location of some of these islands and to explain their origin.

In order to understand the formation of a floating island let us imagine a pond on the edges of which rushes and grasses are growing. These gradually push their way out into the deeper water, leaving a mass of decaying vegetable matter upon which, in time, mosses such as sphagnum may secure a foothold, and start a shelf which will extend out into the water. As soon as the sphagnum has become well established, water-loving plants and shrubs such as alders, sheep laurel and sweet gale will grow with the moss. Cranberries and pitcher plants may also aid in the formation of the mat, forming the familiar cranberry bog. This shelf will be attached to the shore for several feet, the distance depending on the depth of the water, but the peat will seldom attain a thickness of more than three feet. After the mat has become firm, black spruces and larches may grow upon it, often anchoring it and always making it more compact by means of their roots. Such a mat is illustrated by the drawing on page 304.

After the shelf has extended itself some distance into the pond, if the water level is raised unusually high by excessive rainfall or the construction of a dam across the outlet, the mat may break off and form a floating island. This island will either become attached near its former position by roots extending underneath it, or it will float around the lake.

In case the pond is small and nearly circular the mat may surround it. If the water in the pond is raised, at the time when all but the center of the pond is overgrown, an atoll or ring-shaped island may be formed. For the persistence of this atoll the water must remain at its high level and the atoll must become anchored.

Finally, let us suppose that the vegetation completely covered the lake before the water rose. There is sufficient elasticity in such a mat to permit it to rise slightly with a rise in the water level. The mat, however, is not sufficiently elastic to permit its center to rise more than

Cross-section of a Lake, showing a mat of vegetation growing out from both sides. A rise in water level might break off this shelf, and thus form a floating island.

a few feet, if the sides remain attached, and consequently it may disappear with unusually high water. In order for it to reappear either the water must go down or some agency must push the center up higher. This agency is marsh gas. This gas with its light specific gravity could exert such a force on the center of the mat that it would be buoyed up. In order for the gas to act in such a manner it must be present in large quantities and must not escape until that mat has reached the surface. When the gas escapes the mat will again disappear. This alternate appearance and disappearance of the mat makes it a periodic island. A true periodic island would not be attached to the sides. Such islands are rare, and conclusive evidence is lacking to show that they are not attached.

The various ways in which floating islands, floating atolls and periodic islands may originate are as follows:

I. Floating Islands are divided into—(*A*) natural islands and (*B*) artificial islands.

(*A*) Natural islands may be formed by:

1. The coming together of floating vegetable masses. This hypothesis demands sufficient floating material upon which there is plant life of a suitable kind, or upon which plant life may start. There must also be some favorable agency to collect this material. In a large lake where high waves could break off pieces of sphagnum from the shore, the waves might collect the pieces so as to form a floating island. In small lakes, cat-tails or other rushes form a favorable place for such material to lodge.

2. The action of waves beating against a mat of vegetation may by their force break off large islands. This could happen only in the case of a large body of water and would probably account for the origin of the floating island mentioned in the introduction which was seen in the Atlantic Ocean in 1892. When first noticed in July in latitude

Cross-section of Sadawga Lake, Whitingham, Vt., showing two floating islands. The large island grew out from the shore and was broken off by high water. It is now attached at the east side.

39.5° N., longitude 65° W. the island was about 9,000 square feet in extent, with trees thirty feet in height upon it, which made it visible for seven miles. It had apparently become detached from the coast of this country and been carried out to sea by the Gulf Stream. It was again seen in September in latitude 45° 29′ N., longitude 42° 39′ W., after it had passed through a severe storm. By this time it must have traveled over 1,000 nautical miles, and it may have eventually arrived at the coast of Europe.

3. The raising of the water level separates mats from the shore, as previously explained. An interesting case under this heading is that in which there are two kinds of peat in an overflowed bog. If the peat is arranged in layers, the bottom layer being heavy, since it is formed by the decompositon of woody material, may separate from the top layer which is light on account of its sphagnum content. In this circumstance the bottom layer remains in its former position, the upper layer breaking away to form a floating island.

A SECTION OF AN OUTLINE MAP OF NORTH AMERICA, showing the course of a floating island which was seen floating in the Atlantic Ocean in 1892.

4. The action of ice in the northern climates sometimes separates masses of vegetation from the shore. This expansion and contraction of ice is often an important factor in forming shore topography and an overgrowing mat could offer but feeble resistance to this force.

(*B*) Artificial islands may be formed by the damming of ponds or lakes, which is a very common mode of origin of floating islands in this country. An example of this type of island is that in Sadawga Lake shown in cross-section in the second sketch.

II. ATOLLS

Two atolls in central Minnesota. which are characteristic of all such atolls, have been described by Conway MacMillan in the *Minnesota Botanical Studies*,[1] and the following description of them is taken from that article.

> The [larger] pond is about 150 yards across and almost circular in shape. It is surrounded, except for a short distance on the west, by rather precipitous morainic hills 50–75 feet in height. . . . [The atoll] is about 75 feet in diameter and of uniform width of about ten feet. On the west its continuity is broken by a channel, twelve feet across, which furnishes communication between the

[1] 1894, Bul. 9, Vol. 1.

waters of the intra-insular lagoon and those of the pond outside of the atoll. The depth of the water is nowhere great. The greatest depth is about twelve feet and this maximum of depth is in the middle, within the lagoon. . . . The general texture of the atoll was loose, so that one standing anywhere upon it soon sank into the soft and spongy mass up to the knees. . . .

[The smaller] pond is barely fifty yards across, with high banks, and the atoll ring is within a foot or two of twenty yards in diameter. Its breadth, however, is greater than that of [the other] atoll, being twelve feet on the average from the outer to the inner aspect. The lagoon, then, is slightly less than fifty feet across. . . . The water of the pond was shallow, averaging four feet, just outside the atoll ring. . . . In general the texture of the atoll was much firmer than that of [the other] atoll. One could stand anywhere upon it without sinking in above the insteps.

The explanation of the presence of sphagnum atolls may be derived from the assumed changes in level of the pond water, and indeed their presence may, conversely, be held to indicate, or to demonstrate, fluctuations in the pond level. If it be possible to conceive that in these two atoll-producing ponds there has been, during the course of years, a gradual diminution in size followed by a rather rapid increase in diameter and depth, I believe the formation of the atolls would become a phenomenon readily comprehensible. . . . Concomitantly with the diminution in size, doubtless extending over a term of years, vegetation of the shoreward area would have established itself in characteristic zones. The littoral flora and the submerged plants just outside the shores would have formed a loose turf lining the edges of the pond. This turf would have gradually become more solid as it extended landward and would therefore at a little distance from the water's edge have become modified in character, giving a foothold for plants of larger growth. . . . When, subsequently to this epoch of gradual diminution, the ponds began to increase again, the effect of the rise in level of the water was to detach from the shore a ring of the loose littoral turf, and this mass of vegetation with its attendant soil, buoyed up at first as a circular floating bog, appears to-day as the characteristic sphagnum atoll. . . . The increase in size [of the pond] left the annular ring far out in the waters of the pond . . . and as the mass of vegetation and soil became thoroughly saturated with the water below, its character may gradually have changed until

A View of Sadawga Lake, Whitingham, Vt. Two floating islands are shown in the central part of the picture, and behind them is the main floating island from which they have become detached.

ANOTHER VIEW OF SADAWGA LAKE, showing the main floating island (1) and three smaller floating islands which have been broken off from it and have drifted ashore.

the sphagnum plants retained vitality. Generations of these succeeding each other contributed to the weight of the ring and finally pressed it down upon the bottom of the pond, forming the anchored atoll of the present.

[The essential requirements in the formation of atolls are] a small parent pond, height and regularity of banks, regular and gentle slope of the bottom, suitable original littoral vegetation, small lateral pressure and tension of winter ice, and comparatively prompt anchoring of the bottom.

III. Periodic Islands

As previously explained, periodic islands may rise without the formation of gas, but as gas usually escapes from them after they have risen, irrespective of the force causing them to rise, it is a factor which demands attention. Under the average floating island there is little gas, owing to the loose texture of the peat. Consequently, in order to have gas support islands it is necessary that an upper layer of the bog be made of dense material, thus allowing the gas to escape but slowly. The most favorable place for it to collect is between the layers of peat. This is illustrated by experiments[2] in digging peat from a bog filled with water. Holes were dug in the evening of one day and the next morning they were found to be filled with peat masses in the form of domes, cleft in the middle. These domes were formed of one of the lower layers of the peat. The gas under this layer combined with lateral pressure forced it up.

Periodic islands usually rise in spring and sink in fall, owing to the activity of gas-producing organisms in warm water. Some periodic islands have been reported which rose for only a few days. Because of the short time which most of these islands have been known, it has been impossible to study them. Attention is now being given to one in this country and it is to be hoped that through its study valuable information will be obtained regarding this type of island.

[2] Früh und Schröeter, "Die Moore der Schweiz," *Beitr. geol. Schweiz Geotech.*, ser. 3, Bern, 1904.

Professor Whitman and a Group of Research Workers in the Marine Biological Laboratory in 1893

THE PROGRESS OF SCIENCE

PROFESSOR WHITMAN AND THE MARINE BIOLOGICAL LABORATORY

At the annual meeting of the corporation of the Marine Biological Laboratory held at Woods Hole in August, resolutions were adopted recording the obligation of the laboratory to the great man who more than any other was responsible for making it what it is, and after the adjournment of the meeting the trustees and members of the corporation visited the quiet graveyard by the sea where lies the body of Charles Otis Whitman.

Keen
In intellect, with force and skill
To strive, to fashion, to fulfil,

Whitman was born to be a leader. In his zoological researches he exhibited a patience, a balance, a singleness of purpose, a certain classical quality, which placed him among the few worthy to be named with Charles Darwin. His two principal researches, the one on the embryology and phylogeny of the leaches, the other on the phylogeny, heredity and behavior of pigeons, gave rise to a number of papers, which in content and form may be ranked among the masterpieces produced in this country. But in both cases a great part of his work remains unpublished. He was impatient of quick results and sought for fundamental solutions of great problems which perhaps his material was incapable of yielding. There remains, however, a great mass of manuscripts, observations and drawings, together with the unique collection of living pigeons, which will yield a valuable series of publications.

In spite of the fact, or perhaps on account of the fact, that Whitman devoted himself to his research work with complete devotion, he exercised an exceptional influence on zoological education and organization. He was professor in the University of Tokyo at the time when that university was being adapted to modern conditions. When Clark University was organized, he was given charge of the work in zoology, and again on the establishment of the University of Chicago. The department of zoology there, of which he was head until his death, took high rank among the scientific departments, which in a few years have given Chicago distinction in science, equaled only by Harvard and Columbia. Whitman's varied activities are noted in a resolution passed at the Christmas meeting of the Eastern Branch of the American Society of Zoologists, which reads:

The Eastern Branch of the American Society of Zoologists records with profound regret the death of Professor Charles Otis Whitman on December 6, 1910. Professor Whitman was one of the founders of this society; he was chairman of the committee that issued the first call for organization of the American Morphological Society, the forerunner of the American Society of Zoologists, and he was president of the society for the first four years, 1891–94. He was organizer of the *Journal of Morphology* and its editor for many years, and in this capacity also exerted a strong influence on the development of zoological research in America. As director of the Marine Biological Laboratory for twenty-one years, he exerted an even more powerful and entirely unique influence in the development of biological science. As an investigator he was painstaking, enthusiastic and thorough, as a thinker on biological problems profound and far-sighted. Devoted to principle, his uncompromising personality sometimes made enemies, but the charm of his character made him devoted friends. His influence will long remain as one of the most important forces in the history of zoology in America.

The Woods Hole Laboratory was the

institution for which Whitman cared the most and it remains his greatest monument. It is fortunate in its physical environment; still more so in the spirit of the place. More biological research is accomplished there during its season than in any other institution in the world. Both in its formal organization and in its real life it is more democratic than any other American institution devoted to education and research. The result has been, on the one hand, a share of dissensions and poverty; on the other hand, a rare exhibition of cooperation and loyalty. It is false to assume that a democracy should not have leaders. In an autocracy masters hold the reins of authority; in a democracy a leader is followed because he is recognized as such. For many years Whitman was the creative spirit which gave life to the Marine Biological Laboratory. In a note, printed here by permission of Mrs. Whitman, he wrote:

I have often been pleasantly commended for the development of ideal conditions at Woods Hole for cooperative teaching and research, and I think that most of the best friends and patrons of the Marine Biological Laboratory still credit me with qualities that tend to peace and good fellowship in scientific work.

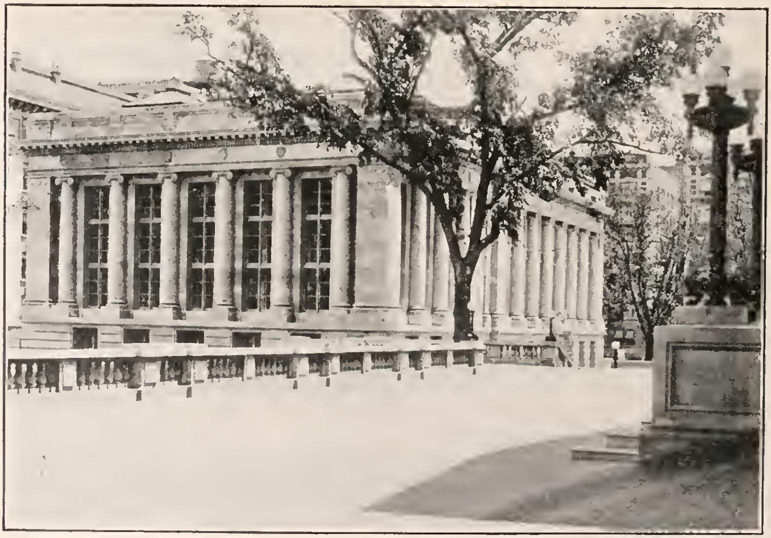
I have, I am happy to say, endeavored to live by the same principles in Chicago. That is, I have done what I could to encourage the spirit of research and good fellowship in both teaching and research.

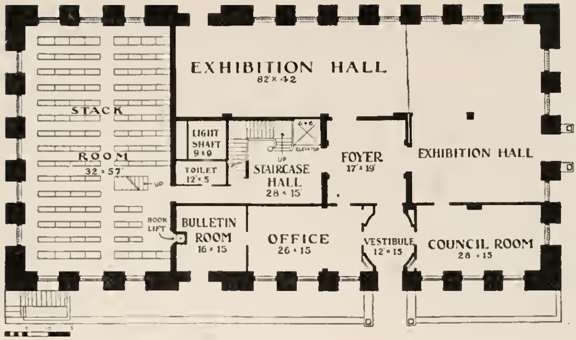
I have opposed all attempts to create interdepartmental kingdoms; I have left each member free to develop his work according to his own taste; have never monopolized any line of work, but have always welcomed synthetic cooperation. The seminar and the researches abundantly verify this.

One thing, from first to last, I have most cordially despised—that is the tendency to that disease, which we may distinguish as administro-citis. That disease is the peril of science, and the source of unwholesome strife. Our organization is of course largely at fault, for it certainly misleads many to imagine that the one sure road to precedence is to scheme for it through administrative dexterity.

THE AMERICAN GEOGRAPHICAL SOCIETY

The American Geographical Socieity, which was founded in New York City in 1852 and has now about 1,300 members, moved ten years ago to a building opposite the American Museum of Natural History. But it soon outgrew





its quarters and has now again moved to a new site on Broadway and 156th Street, adjacent to the fine buildings of the Hispanic Society of America and the American Numismatic and Archeological Society. It has now a beautiful site by the Hudson River in one of the scientific centers of the city. It is unfortunate that all the institutions devoted to higher education, science and letters could not have been placed in one center, but they are at all events in large measure connected by the subway on the west side of the city.

By the courtesy of Mr. F. S. Dellenbaugh, the secretary of the society, we are able to print here some illustrations showing the exterior and interior of the admirable new building, which has been occupied by the society since May. It is built of Indiana limestone in the style of the Italian Renaissance, conforming to the other buildings on the ground. There are four stories and a basement; the stack rooms form the western part of the building, being placed on six floors. The whole building is admirably designed for the purposes of a geographical society, being completely fire-proof, with ample light on all sides. It will provide a permanent home for the library and collections of the society and for its educational and scientific work.

SCIENTIFIC ITEMS

We regret to record the deaths of Professor Benjamin Franklin Thomas, professor of physics in the Ohio State

University, and of Dr. Johann Paul Schweitzer, emeritus professor of chemistry in the University of Missouri.

The Paris Academy of Sciences has awarded its Lalande Prize to Dr. Lewis Boss, director of the Dudley Observatory, Albany, N. Y. Its general prizes, each of the value of $2,000, have been awarded to M. Jules Tannery, of Paris, for his mathematical publications, and to M. Déperet, of Lyons, for his geological publications.

Professor L. H. Bailey has tendered to the trustees of Cornell University his resignation as director of the New York State College of Agriculture.—Dr. E. C. Franklin, professor of organic chemistry at Stanford University, has become professor of chemistry in the hygienic laboratory of the Public Health and Marine-Hospital Service.—Professor Clyde Furst, secretary of Teachers College, Columbia University, since 1902, has become secretary of the Carnegie Foundation for the Advancement of Teaching, succeeding Mr. John G. Bowman, who has become president of the University of Iowa.—The director of the Museo Nacional, Mexico, Sr. Garcia has resigned and Sr. Robelo has been appointed in his place. Sr. Batres, inspector of antiquities, is succeeded by Sr. Rodriguez.

THE POPULAR SCIENCE MONTHLY

OCTOBER, 1911

GENETICS[1]

By W. BATESON, M.A., F.R.S.

THE invitation to preside over the agricultural sub-section on this occasion naturally gave me great pleasure, but after accepting it I have felt embarrassment in a considerable degree. The motto of the great society which has been responsible for so much progress in agricultural affairs in this country very clearly expresses the subject of our deliberations in the words "Practise with Science," and to be competent to address you, a man should be well conversant with both. But even if agriculture is allowed to include horticulture, as may perhaps be generally conceded, I am sadly conscious that my special qualifications are much weaker than you have a right to demand of a president.

The aspects of agriculture from which it offers hopeful lines for scientific attack are, in the main, three: Physiological, pathological and genetic. All are closely interrelated, and for successful dealing with the problems of any one of these departments of research, knowledge of the results attained in the others is now almost indispensable. I myself can claim personal acquaintance with the third or genetic group alone, and therefore in considering how science is to be applied to the practical operations of agriculture, I must necessarily choose it as the more special subject of this address. I know very well that wider experience of those other branches of agricultural science or practical agriculture would give to my remarks a weight to which they can not now pretend.

Before, however, proceeding to these topics of special consideration, I have thought it not unfitting to say something of a more general nature as to the scope of an applied science, such as that to which we here are devoted. We are witnessing a very remarkable outburst of activity in the promotion of science in its application to agriculture.

[1] Address to the Agricultural Sub-section of the British Association for the Advancement of Science.

Public bodies distributed throughout this country and our possessions are organizing various enterprises with that object. Agricultural research is now everywhere admitted a proper subject for university support and direction.

With the institution of the development grant a national subsidy is provided on a considerable scale in England for the first time.

At such a moment the scope of this applied science and the conditions under which it may most successfully be advanced are prominent matters of consideration in the minds of most of us. We hope great things from these new ventures. We are, however, by no means the first to embark upon them. Many of the other great nations have already made enormous efforts in the same direction. We have their experience for a guide.

Now, it is not in dispute that wherever agricultural science has been properly organized valuable results have been attained, some of very high importance indeed; yet with full appreciation of these achievements, it is possible to ask whether the whole outcome might not have been greater still. In the course of recent years I have come a good deal into contact with those who in various countries are taking part in such work, and I have been struck with the unanimity that they have shown in their comments on the conditions imposed upon them. Those who receive large numbers of agriculture bulletins purporting to give the results of practical trials and researches will, I feel sure, agree with me that with certain notable exceptions they form on the whole dull reading. True they are in many cases written for farmers and growers in special districts, rather than for the general scientific reader, but I have sometimes asked myself whether those farmers get much more out of this literature than I do. I doubt it greatly. Nevertheless, to the production of these things much labor and expense have been devoted. I am sure, and I believe that most of those engaged in these productions themselves feel, that the effort might have been much better applied elsewhere. Work of this unnecessary kind is done, of course, to satisfy a public opinion which is supposed to demand rapid returns for outlay, and to prefer immediate apparent results, however trivial, to the long delay which is the almost inevitable accompaniment of any serious production. For my own part, I greatly doubt whether in this estimate present public opinion has been rightly gauged. Enlightenment as to the objects, methods and conditions of scientific research is proceeding at a rapid rate. I am quite sure, for example, that no organization of agricultural research now to be inaugurated under the Development Commission will be subjected to the conditions laid down in 1887 when the experimental stations of the United States were established. From them it is decreed in Sec. 4 of the Act of Establishment:

That bulletins or reports of progress shall be published at said stations at least once in three months, one copy of which shall be sent to each newspaper in the states or territories in which they are respectively located, and to such individuals actually engaged in farming as may request the same and as far as the means of the station will permit.

It would be difficult to draft a condition more unfavorable to the primary purpose of the Act, which was "to conduct original researches or verify experiments on the physiology of plants and animals." I can scarcely suppose the most prolific discoverer should be invited to deliver himself more than once a year. Not only does such a rule compel premature publication—that nuisance of modern scientific life—but it puts the investigator into a wrong attitude towards his work. He will do best if he forget the public and the newspaper of his state or territory for long periods, and should only return to them when, after repeated verification, he is quite certain he has something to report.

In this I am sure the best scientific opinion of all countries would be agreed. If it is true that the public really demand continual scraps of results, and can not trust the investigators to pursue research in a reasonable way, then the public should be plainly given to understand that the time for inaugurating researches in the public's name has not arrived. Men of science have in some degree themselves to blame if the outer world has been in any mistake on these points. It can not be too widely known that in all sciences, whether pure or applied, research is nearly always a very slow process, uncertain in production, and full of disappointments. This is true, even in the new industries, chemical and electrical, for instance, where the whole industry has been built up from the beginning on a basis developed entirely by scientific method and by the accumulation of precise knowledge. Much more must any material advance be slow in the case of an ancient art like agriculture, where practise represents the casual experience of untold ages and accurate investigation is of yesterday. Problems moreover relating to unorganized matter are in their nature simpler than those concerned with the properties of living things, a region in which accurate knowledge is more difficult to attain. Here the research of the present day can aspire no higher than to lay the foundation on which the following generations will build. When this is realized it will at once be perceived that both those who are engaged in agricultural research and those who are charged with the supervision and control of these researches must be prepared to exercise a large measure of patience.

The applicable science must be created before it can be applied. It is with the discovery and development of such science that agricultural research will for long enough best occupy its energies. Sometimes, truly, there come moments when a series of obvious improvements in practise can at once be introduced, but this happens only when the penetrative genius of a Pasteur or a Mendel has worked out the way into a new region of knowledge, and returns with a treasure that all can use. Given the knowledge it will soon enough become applied.

I am not advocating work in the clouds. In all that is attempted we must stick near to the facts. Though the methods of research and of thought must be strict and academic, it is in the farm and the garden that they must be applied. If inspiration is to be found anywhere it will be there. The investigator will do well to work

As if his highest plot
To plant the bergamot.

It is only in the closest familiarity with phenomena that we can attain to that perception of their orderly relations, which is the beginning of discovery.

To the creation of applicable science the very highest gifts and training are well devoted. In a foreign country an eminent man of science was speaking to me of a common friend, and he said that as our friend's qualifications were not of the first rank he would have to join the agricultural side of the university. I have heard remarks of similar disparagement at home. Now, whether from the standpoint of agriculture or pure science, I can imagine no policy more stupid and short-sighted.

The man who devotes his life to applied science should be made to feel that he is in the main stream of scientific progress. If he is not, both his work and science at large will suffer. The opportunities of discovery are so few that we can not afford to miss any, and it is to the man of trained mind who is in contact with the phenomena of a great applied science that such opportunities are most often given. Through his hands pass precious material, the outcome sometimes of years of effort and design. To tell him that he must not pursue that inquiry further because he can not foresee a direct and immediate application of the knowledge he would acquire, is, I believe almost always, a course detrimental to the real interests of the applied science. I could name specific instances where in other countries thoroughly competent and zealous investigators have by the shortsightedness of superior officials been thus debarred from following to their conclusion researches of great value and novelty.

In this country where the Development Commission will presumably for many years be the main instigator and controller of agricultural research, the constitution of the advisory board, on which science is largely represented, forms a guarantee that broader counsels will prevail, and it is to be hoped that not merely this inception of the work, but its future administration also will be guided in the same spirit.

So long as a train of inquiry continues to extend, and new knowledge, that most precious commodity, is coming in the enterprise will not be in vain and it will be usually worth while to pursue it.

The relative value of the different parts of knowledge in their application to industry is almost impossible to estimate, and a line of work should not be abandoned until it leads to a dead end, or is lost in a desert of detail.

We have, not only abroad, but also happily in this country, several private firms engaged in various industries—I may mention especially metallurgy, pharmacy and brewing—who have set an admirable example in this matter, instituting researches of a costly and elaborate nature, practically unlimited in scope, connected with the subjects of their several activities, conscious that it is only by men in close touch with the operations of the industry that the discoveries can be made, and well assured that they themselves will not go unrewarded.

Let us on our part beware of giving false hopes. We know no hæmony "of sovran use against all enchantments, mildew blast, or damp." Those who are wise among us do not even seek it yet. Why should we not take the farmer and gardener into our fullest confidence and tell them this? I read lately a newspaper interview with a fruit-farmer who was being questioned as to the success of his undertaking, and spoke of the pests and difficulties with which he had had to contend. He was asked whether the Board of Agriculture and the scientific authorities were not able to help him. He replied that they had done what they could, that they had recommended first one thing and then another, and he had formed the opinion that they were only in an experimental stage. He was perfectly right, and he would hardly have been wrong had he said that in these things science is only approaching the experimental stage. This should be notorious. There is nothing to extenuate. To affect otherwise would be unworthy of the dignity of science.

Those who have the means of informing the public mind on the state of agricultural science should make clear that though something can be done to help the practical man already, the chief realization of the hopes of that science is still very far away, and that it can only be reached by long and strenuous effort, expended in many various directions, most of which must seem to the uninitiated mere profitless wandering. So only will the confidence of the laity be permanently assured towards research.

Nowhere is the need for wide views of our problems more evident than in the study of plant-diseases. Hitherto this side of agriculture and of horticulture, though full of possibilities for the introduction of scientific method, has been examined only in the crudest and most empirical fashion. To name the disease, to burn the affected plants and to ply the crop with all the sprays and washes in succession ought not to be regarded as the utmost that science can attempt. There is at the present time hardly any comprehensive study of the morbid physiology of plants comparable with that which has been so greatly developed in application to animals. The nature of the resistance to disease characteristic of so many varieties, and the modes by which it may be ensured, offers a most attractive field for research, but it is one in which the advance must be made by the development of pure science, and those who engage in it must be prepared for a long period of labor without ostensible practical results. It has seemed to me that the most likely method of attack is here, as often, an indirect one. We should probably do best if we left the direct and special needs of agriculture for a time out of account, and enlisted the services of pathologists trained in the study of disease as it affects man and animals, a science already developed and far advanced towards success. Such a man, if he were to devote himself to the investigation of the same problems in the case of plants could, I am convinced, make discoveries which would not merely advance the theory of disease-resistance in general very greatly, but would much promote the invention of rational and successful treatment.

As regards the application of genetics to practise, the case is not very different. When I go to the Temple Show or to a great exhibition of live stock, my first feeling is one of admiration and deep humility. Where all is so splendidly done and results so imposing are already attained, is it not mere impertinence to suppose that any advice we are able to give is likely to be of value?

But as soon as one enters into conversation with breeders, one finds that almost all have before them some ideal to which they have not yet attained, operations to perform that they would fain do with greater ease and certainty, and that as a matter of fact, they *are* looking to scientific research as a possible source of the greater knowledge which they require. Can we, without presumption, declare that genetic science is now able to assist these inquirers? In certain selected cases it undoubtedly can—and I will say, moreover, that if the practical men and we students could combine our respective experiences into one head, these cases would already be numerous. On the other hand, it is equally clear that in a great range of examples practise is so far ahead that science can scarcely hope in finite time even to represent what has been done, still less to better the performance. We can not hope to improve the Southdown sheep for its own districts, to take a second off the trotting record, to increase the flavor of the muscat of Alexandria, or to excel the orange and pink of the rose Juliet. Nothing that we know could have made it easier to produce the Rambler roses, or even to evoke the latest novelties in sweet peas, though it may be claimed that the genetic system of the sweet pea is, as things go, fairly well understood. To do any of these things would require a control of events so lawless and rare that for ages they must probably remain classed as accidents. On the other hand, the modes by which combinations can be made, and by which new forms can be fixed, are through Mendelian analysis and the recent developments of genetic science now reasonably clear, and with that knowledge much of the breeder's work is greatly simplified. This part of the subject is so well understood that I need scarcely do more than allude to it.

A simple and interesting example is furnished by the work which Mr. H. M. Leake is carrying out in the case of cotton in India. The cottons of fine quality grown in India are monopodial in habit, and are consequently late in flowering. In the United Provinces a comparatively early-flowering form is required, as otherwise there is not time for the fruits to ripen. The early varieties are sympodial in habit, and the primary apex does not become a flower. Hitherto no sympodial form with cotton of high quality has existed, but Mr. Leake has now made the combination needed, and has fixed a variety with high-class cotton and the sympodial habit, which is suitable for cultivation in the United Provinces. Until genetic physiology was developed by Mendelian analysis, it is safe to say that a practical achievement of this kind could not have been made with rapidity or certainty. The research was planned on broad lines. In the course of it much light was obtained on the genetics of cotton, and features of interest were discovered which considerably advance our knowledge of heredity in several important respects. This work forms an admirable illustration of that simultaneous progress both towards the solution of a complex physiological problem and also towards the successful attainment of an economic object which should be the constant aim of agricultural research.

Necessarily it follows that such assistance as genetics can at present give is applicable more to the case of plants and animals which can be treated as annuals than to creatures of slower generation. Yet this already is a large area of operations. One of the greatest advances to be claimed for the work is that it should induce raisers of seed crops especially to take more hopeful views of their absolute purification than have hitherto prevailed. It is at present accepted as part of the natural perversity of things that most high-class seed crops must throw "rogues," or that at the best the elimination of these waste plants can only be attained by great labor extended over a vast period of time. Conceivably that view is correct, but no one acquainted with modern genetic science can believe it without most cogent proof. Far more probably we should regard these rogues either as the product of a few definite individuals in the crop, or even as chance impurities brought in by accidental mixture. In either case they can presumably be got rid of. I may even go further and express a doubt whether that degeneration which is vaguely supposed to be attendant on all seed crops is a physiological reality. Degeneration may perhaps affect plants like the potato which are continually multiplied asexually, though the fact has never been proved satisfactorily. Moreover it is not in question that races of plants taken into unsuitable climates do degenerate rapidly from uncertain causes, but that is quite another matter.

The first question is to determine whether a given rogue has in it any factor which is *dominant* to the corresponding character in the typical plants of the crop. If it has, then we may feel considerable confidence that these rogues have been introduced by accidental mixture. The only alternative, indeed, is cross-fertilization with some distinct variety possessing the dominant, or crossing within the limits of the typical plants themselves occurring in such a way that complementary factors have been brought together. This last is a comparatively infrequent phenomenon, and need not be considered till more probable hypotheses have been disposed of. If the rogues are first crosses the fact can be immediately proved by sowing their seeds, for segregation will then be evident. For example, a truly round seed is occasionally, though very rarely, found on varieties of pea which have wrinkled seeds. I have three times seen such seeds on my own plants. A few more were kindly given me by Mr. Arthur Sutton, and I have also received a few from M. Philippe de Vilmorin—to both of whom I am indebted for most helpful assistance and advice. Of these abnormal or unexpected seeds some died without germinating, but all which did germinate in due course produced the normal mixture of round and wrinkled, proving that a cross had occurred. Cross-fertilization in culinary peas is excessively rare, but it is certainly sometimes effected, doubtless by the leaf-cutter bee (*Megachile*) or a humble-bee visiting flowers in which for some reason the pollen has been inoperative. But in peas crossing is assuredly not the source of the ordinary rogues. These plants have a very peculiar conformation, being tall and straggling, with long internodes, small leaves and small flowers, which together give them a curious wild look. When one compares them with the typical cultivated plants which have a more luxuriant habit, it seems difficult to suppose that the rogue can really be recessive in such a type. True, we can not say definitely *a priori* that any one character is dominant to another, but old preconceptions are so strong that without actual evidence we always incline to think of the wilder and more primitive characteristics as dominants. Nevertheless, from such observations as I have been able to make I can not find any valid reason for doubting that the rogues are really recessives to the type. One feature in particular is quite inconsistent with the belief that these rogues are in any proper sense degenerative returns to a wild type, for in several examples the rogues have *pointed* pods like the cultivated sorts from which they have presumably been derived. All the more primitive kinds have the dominant stump-ended pod. If the rogues had the stump pods they would fall in the class of dominants, but they have no single quality which can be declared to be certainly dominant to the type, and I see no reason why they may not be actually recessives to it after all. Whether this is the true account or not we shall know for certain next year. Mr. Sutton has given me a quantity of material which we are now investigating at the John Innes Horticultural Institution, and by sowing the seed of a great number of individual plants separately I anticipate that we shall prove the rogue-throwers to be a class apart. The pure types then separately saved should, according to expectation, remain rogue-free, unless further sporting or fresh contamination occurs. If it prove that the long and attenuated rogues are really recessive to the shorter and more robust type, the case will be one of much physiological significance, but I believe a parallel already exists in the case of wheats, for among certain crosses bred by Professor Biffen, some curious spelt-like plants occurred among the derivatives from such robust wheats as Rivet and Red Fife.

There is another large and important class of cases to which similar considerations apply. I refer to the bolting or running to seed of crops grown as biennials, especially root crops. It has hitherto been universally supposed that the loss due to this cause, amounting in sugar beet as it frequently does to five, or even more, per cent., is not preventable. This may prove to be the truth, but I think it is not impossible that the bolters can be wholly, or almost wholly, eliminated by the application of proper breeding methods. In this particular example I know that season and conditions of cultivation count for a good deal in promoting or checking the tendency to run to seed, nevertheless one can scarcely witness the sharp distinction between the annual and biennial forms without suspecting that genetic composition is largely responsible. If it proves to be so, we shall have another remarkable illustration of the direct applicability of knowledge gained from a purely academic source. "Let not him that putteth his armor on boast him as he that putteth it off," and I am quite alive to the many obstacles which may lie between the conception of an idea and its realization. One thing, however, is certain, that we have now the power to formulate rightly the question which the breeder is to put to nature; and this power and the whole apparatus by which he can obtain an answer to his question—in whatever sense that answer may be given—has been derived from experiments designed with the immediate object of investigating that scholastic and seemingly barren problem, "What is a species?" If Mendel's eight years' work had been done in an agricultural school supported by public money, I can imagine much shaking of heads on the county council governing that institution, and yet it is no longer in dispute that he provided the one bit of solid discovery upon which all breeding practise will henceforth be based.

Everywhere the same need for accurate knowledge is apparent. I suppose horse-breeding is an art which has by the application of common sense and great experience been carried to about as high a point of perfection as any. Yet even here I have seen a mistake made which is obvious to any one accustomed to analytical breeding. Among a number of stallions provided at great expense to improve the breed of horses in a certain district was one which was shown me as something of a curiosity. This particular animal had been bred by one of the provided stallions out of an indifferent country mare. It had been kept as an unusually good-looking colt, and was now traveling the country as a breeding stallion, under the highest auspices. I thought to myself that if such a practise is sanctioned by breeding acumen and common sense, science is not after all so very ambitious if she aspires to do rather better. The breeder has continually to remind himself that it is not what the animal or plant *looks* that matters, but what it *is*. Analysis has taught us to realize, first, that each animal and plant is a double structure, and next that the appearance may show only half its composition.

With respect to the inheritance of many physiological qualities of divers kinds we have made at least a beginning of knowledge, but there is one class of phenomena as yet almost untouched. This is the miscellaneous group of attributes which are usually measured in terms of size, fertility, yield and the like. This group of characters has more than common significance to the practical man. Analysis of them can nevertheless only become possible when pure science has progressed far beyond the point yet reached.

I know few lines of pure research more attractive and at the same time more likely to lead to economic results than an investigation of the nature of variation in size of the whole organism or of its parts. By what factors is it caused? By what steps does it proceed? By what limitations is it beset? In illustration of the application of these questions I may refer to a variety of topics that have been lately brought to my notice. In the case of merino sheep I have been asked by an Australian breeder whether it is possible to combine the optimum length of wool with the optimum fineness and the right degree of crimping. I have to reply that absolutely nothing is yet known for certain as to the physiological factors determining the length or the fineness of wool. The crimping of the fibers is an expression of the fact that each particular hair is curved, and if free and untwisted would form a corkscrew spiral, but as to the genetics of curly hair even in man very little is yet known. But leaving the question of curl on one side, we have in regard to the length and fineness of wool, a problem which genetic experiment ought to be able to solve. Note that in it, as in almost all problems of the "yield" of any product of farm or garden, two distinct elements are concerned—the one is *size,* and the other is *number.* The length of the hair is determined by the rate of excretion and length of the period of activity of the hair follicles, but the fineness is determined by the number of follicles in unit area. Now analogy is never a safe guide, but I think if we had before us the results of really critical experiments on the genetics of size and number of multiple organs in any animal or even any plant, we might not wholly be at a loss in dealing with this important problem.

A somewhat similar question comes from South Africa. Is it possible to combine the qualities of a strain of ostriches which has extra long plumes with those of another strain which has its plumes extra lustrous? I have not been able fully to satisfy myself upon what the luster depends, but I incline to think it is an expression of fineness of fiber, which again is probably a consequence of the smallness and increased number of the excreting cells, somewhat as the fineness of wool is a consequence of the increased number and smallness of the excreting follicles.

Again the question arises in regard to flax, how should a strain be bred which shall combine the maximum length with maximum fineness of fiber? The element of number comes in here, not merely with regard to the number of fibers in a stem, but also in two other considerations, first, that the plant should not tiller at the base, and, secondly, that the decussation of the flowering branches should be postponed to the highest possible level.

Now in this problem of the flax, and not impossibly in the others I have named, we have questions which can in all likelihood be solved in a form which will be of general, if not of universal, application to a host of other cognate questions. By good luck the required type of flax may be struck at once, in which case it may be fixed by ordinary Mendelian analysis, but if the problem is investigated by accurate methods on a large scale, the results may show the way into some of those general problems of size and number which make a great part of the fundamental mystery of growth.

I see no reason why these things should remain inscrutable. There is indeed a little light already. We are well acquainted with a few examples in which the genetic behavior of these properties is fairly definite. We have examples in which, when two varieties differing in number of divisions are crossed, the lower number dominates—or, in other words, that the increased number is a consequence of the removal of a factor which prevents or inhibits particular divisions, so that they do not take place. It is likely that in so far as the increased productivity of a domesticated form as compared with its wild original depends on more frequent division, the increase is due to loss of inhibiting factors. How far may this reasoning be extended? Again we know that in several plants—peas, sweet peas, *Antirrhinum* and certain wheats—a tall variety differs in that respect from a dwarf in possessing one more factor. It would be an extraordinarily valuable addition to knowledge if we could ascertain exactly how this factor operates, how much of its action is due to linear repetition, and how much to actual extension of individual parts. The analysis of the plants of intermediate size has never been properly attempted, but would be full of interest and have innumerable bearings on other cases in animals and plants, some of much economic importance.

That in all such examples the objective phenomena we see are primarily the consequence of the interaction of genetic factors is almost certain. The lay mind is at first disposed, as always, to attribute such distinctions to anything rather than to a specific cause which is invisible. An appeal to differences in conditions—which a moment's reflection shows to be either imaginary or altogether independent—or to those vague influences invoked under the name of selection, silently postponing any laborious analysis of the nature of the material selected, repels curiosity for a time, and is lifted as a veil before the actual phenomena; and so even critical intelligences may for an indefinite time be satisfied that there is no specific problem to be investigated, in the same facile way that, till a few years ago, we were all content with the belief that malarial fevers could be referred to any damp exhalations in the atmosphere, or that in suppuration the body was discharging its natural humors. In the economics of breeding, a thousand such phenomena are similarly waiting for analysis and reference to their specific causes. What, for instance, is self-sterility? The phenomenon is very widely spread among plants, and is far commoner than most people suppose who have not specially looked for it. Why is it that the pollen of an individual in these plants fails to fertilize the ova of the same individual? Asexual multiplication seems in no way to affect the case. The American experimenters are doubtless right in attributing the failure of large plantations of a single variety of apples or of pears in a high degree to this cause. Sometimes, as Mr. W. O. Backhouse has found in his work on plums at the John Innes Horticultural Institution, the behavior of the varieties is most definite and specific. He carefully self-fertilized a number of varieties, excluding casual pollination, and found that while some sorts, for example, Victoria, Czar and Early Transparent set practically every fruit self-pollinated, others including several (perhaps all) Greengages, Early Orleans and Sultan do not set a single fruit without pollination from some other variety.

Dr. Erwin Baur has found indications that self-sterility in *Antirrhinum* may be a Mendelian recessive, but whether this important suggestion be confirmed or not, the subject is worth the most minute study in all its bearings. The treatment of this problem well illustrates the proper scope of an applied science. The economic value of an exact determination of the empirical facts is obvious, but it should be the ambition of any one engaging in such a research to penetrate further. If we can grasp the *rationale* of self-sterility we open a new chapter in the study of life. It may contain the solution of the question, What is an individual?—no mere metaphysical conundrum, but a physiological problem of fundamental significance.

What, again, is the meaning of that wonderful increase in size or in "yield" which so often follows on a first cross? We are no longer content, as Victorian teleology was, to call it a "beneficial" effect and pass on. The fact has long been known and made use of in breeding stock for the meat market, and of late years the practise has also been introduced in raising table poultry. Mr. G. N. Collins,[2] of the U. S. Department of Agriculture, has recently proposed with much reason that it might be applied in the case of maize. The cross is easy to make on a commercial scale, and the gain in yield is striking, the increase ranging as high as 95 per cent. These figures sound extravagant, but from what I have frequently seen in peas and sweet peas, I am prepared for even greater increase. But what *is* this increase? How much of it is due to change in number of parts, how much to transference of differentiation or homœosis, as I have called it—leaf-buds becoming flower-buds, for instance—and how much to actual increase in size of parts? To answer these questions would be to make an addition to human knowledge of incalculably great significance.

Then we have the further question, How and why does the increase disappear in subsequent generations? The very uniformity of the cross-breds between pure strains must be taken as an indication that the phenomenon is orderly. Its subsidence is probably orderly also. Shull has advocated the most natural view that heterozygosis is the exciting cause, and that with the gradual return to the homozygous state the effects pass off. I quite think this may be a part of the explanation, but I feel difficulties, which need not here be detailed, in accepting this as a complete account. Some of the effect we may probably also attribute to the combination of complementary factors; but whether heterozygosis, or complementary action, is at work, our experience of cross-breeding in general makes it practically certain that genetic factors of special classes only can have these properties, and no pains should be spared in identifying them. It is not impossible that such identifi-

[2] Bureau of Plant Industry, Bulletin No. 191, 1910.

cation would throw light on the nature of cell division and of that meristic process by which the repeated organs of living things are constituted, and I have much confidence that in the course of the analysis discoveries will be made bearing directly both on the general theory of heredity and on the practical industry of breeding.

In the application of science to the arts of agriculture, chemistry, the foundation of sciences, very properly and inevitably came first, while breeding remained under the unchallenged control of simple common sense alone. The science of genetics is so young that when we speak of what it also can do we must still for the most part ask for a long credit; but I think that if there is full cooperation between the practical breeder and the scientific experimenter, we shall be able to redeem our bonds at no remotely distant date. In the mysterious properties of the living bodies of plants and animals there is an engine capable of wonders scarcely yet suspected, waiting only for the constructive government of the human mind. Even in the seemingly rigorous tests and trials which have been applied to living material apparently homogeneous, it is not doubtful that error has often come in by reason of the individual genetic heterogeneity of the plants and animals chosen. A batch of fruit trees may be all of the same variety, but the stocks on which the variety was grafted have hitherto been almost always seminally distinct individuals, each with its own powers of luxuriance or restriction, their own root-systems and properties so diverse that only in experiments on a colossal scale can this diversity be supposed to be levelled down. Even in a closely bred strain of cattle, though all may agree in their "points," there may still be great genetic diversity in powers of assimilation and rapidity of attaining maturity, by which irregularities by no means negligible are introduced. The range of powers which organic variation and genetic composition can confer is so vast as to override great dissimilarities in the conditions of cultivation. This truth is familiar to every raiser and grower who knows it in the form that the first necessity is for him to get the right breed and the right variety for his work. If he has a wheat of poor yield, no amount of attention to cultivation or manuring will give a good crop. An animal that is a bad doer will remain so in the finest pasture. All praise and gratitude to the student of the conditions of life, for he can do, and has done, much for agriculture, but the breeder can do even more.

When more than fifteen years ago the proposal to found a school of agriculture in Cambridge was being debated, much was said of the importance of the chemistry of soils, of researches into the physiological value of food-stuffs, and of other matters then already prominent on the scientific horizon. I remember then interpolating with an appeal for some study of the physiology of breeding, which I urged should find a place in the curriculum, and I pointed out that the improvement in the strains of plants and animals had done at least as much —more, I really meant—to advance agriculture than had been accomplished by other means. My advice found little favor, and I was taken to task, afterwards, by a prominent advocate of the new school for raising a side issue. Breeding was a purely empirical affair. Common sense and selection comprised the whole business, and physiology flew at higher game. I am, nevertheless, happy now to reflect that of the work which is making the Cambridge School of Agriculture a force for progress in the agricultural world the remarkable researches and results of my late colleague, Professor Biffen, based as they have been on modern discoveries in the pure sciences of breeding, occupy a high and greatly honored place.

In conclusion I would sound once more the note with which I began. If we are to progress fast there must be no separation made between pure and applied science. The practical man with his wide knowledge of specific natural facts, and the scientific student ever seeking to find the hard general truths which the diversity of nature hides —truths out of which any lasting structure of progress must be built —have everything to gain from free interchange of experience and ideas. To ensure this community of purpose those who are engaged in scientific work should continually strive to make their aims and methods known at large, neither exaggerating their confidence nor concealing their misgivings,

> Till the world is wrought
> To sympathy with hopes and fears it heeded not.

CIVILIZATION AND VEGETATION

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CERTAIN experiences, national and personal, have caused me to reflect of late on this subject, the outlines and meaning of which will become clear, I hope, as we proceed.

With the modesty which we all recognize to be the supreme characteristic distinguishing man from all other living organisms, we regard the human race as the dominant one in nature. We consider it not only the one whose mental, if not physical, evolution has proceeded furthest toward the highest good, but the one which by natural or divine right should subjugate and rule all others, should domesticate or exterminate at will, should plow or disembowel the earth, should make the desert bear crops or strip the slopes of their forest cover, centuries old. In fact, so complete is human modesty, that the race does all these things and many more with no thought but as to the means and the gain, never a question as to the right. That is modestly assumed.

Human modesty even goes so far as to compel competition among men. The gross material cannibalism that once prevailed has given place to that refined cannibalism which, on bourse and stock exchange, in manufacture and sale of commodities, even in the numberless Olympuses of our American colleges, "eats up" the "lambs," devours the weak competitor, and oppresses the friendless. Peace is not in the scheme of nature, that nature in which man has taken the rôle of Ishmael, whose hand was against every man and every man's hand against him.

With this Ishmael, as in all nature, struggle is universal and inevitable; struggle, competition, war if you will, which can have only one end, the extermination of one of the strugglers. There is such a thing as extermination by assimilation. The King of the Cannibal Islands exterminated the first missionaries by assimilating them after murder. We are to-day exterminating the Indian as such by assimilating him without murder as certainly as in the days of the Indian wars.

Where are the races of wild animals from which we have "developed" cows and hens, the intelligence, alertness and gaiety of whose countenances is so obvious? We have assimilated them. Some of their excellences have even been imitated on the stage.

What is the joy of living as a tame hen, as a domesticated cow, as a pruned pear tree? "The ox that treadeth out corn" is sure of daily food; so is "the cock of the walk"; so also are the subjugated plants of farm and garden; but individuality has been sacrificed for safety, they have been conquered in the war which every man is waging against every other living thing, human or other.

Whether the Ishmaelitic rôle of man in nature be right or wrong, it is very real, and we can not escape playing our share in that rôle. It may be merely as competitors against other human beings, holding the positions which others would like, but which we call ours; or it may be as competitors against other kinds of organisms.

On beautiful spring days, when the country calls us from desk and laboratory, we see the fields turning over under the plow, the wild flowers, the native shrubs, and the young trees existing, if at all, only in the fence corners, the trees and other plants of the wood-lot leaping their bounds only to be killed bye and bye by the cultivator. In place of the variety which once covered an acre, we shall presently see only a waving field of grain, wheat or barley or oats, no one of which is native; or there will come up corn in formal rows which can reach its hypertrophic maturity only by the destruction of numberless smaller plants of which this field was once the possession. Or the unnatural trees of an orchard shade a hillside on which once stood a forest, and in place of clear streams the air tinkles with the music of brooks and creeks turbid with soil and perhaps infected with typhoid.

This last is an evidence of revenge. Civilization and man do not have things without struggle, although the outcome of the struggle is certain. Civilization and man will triumph, but not without great mortality on both sides. In the natural forest and on the natural prairie, untouched by man's invasion or by fire or by other profound disturbance, the balance is fairly maintained year after year. Last summer in the northern Rockies, I was struck by the fact that the forest does not encroach on the grass land, nor this spread into the timber. Generation after generation, they are the same, with great grassy bays here and there into the forest and high capes and promontories of timber stretching out into the grazing land. The trees and the grasses bear and shed seed year by year; insects eat the foliage or tunnel bark and wood; parasitic fungi cause smut or rust or rot; but neither set of enemies produces an epidemic or decimates the plant population, nor does the population greatly change. But let man clear the land of its stable native population, and the difference is at once apparent. If he attempt to raise a crop, he must fight as a weed every native plant, or cut back the timber to secure sunshine; he must drain his fields of excessive moisture, but in such manner as to conserve enough; he must till so that fresh soil may be brought to the roots of successive crops; and he must soon begin the endless use of insecticides, fungicides and fertilizers because of the apparently sudden increase in enemies and decrease in fertility. This is what he pays for trying to substitute his balance of population for that of nature. By tools and sprays he drives back the larger and more minute representatives of the former population until finally they are to be found only in such places as man may not yet wish to use for the other purposes. In Muir's "Mountains of California," in the chapter entitled The Bee-Pastures, he describes what used to be. "The Great Central Plain of California during the months of March, April and May, was one smooth continuous bed of honey-bloom, so marvellously rich that in walking from one end of it to the other, a distance of 400 miles, your foot would press about a hundred flowers at every step. The radiant honey-filled corollas, touching and over lapping, and rising above one another, glowed in the living light like a sunset sky—one sheet of purple and gold, with the bright Sacramento pouring through the midst of it from the north, the San Joaquin from the south, and their many tributaries sweeping in at right angles from the mountains, dividing the plain into sections fringed with trees." Now that plain is a checkerboard of grain and alfalfa fields bounded by irrigation ditches. And the lesser valleys, parallel with this great central plain, bounded by mountains still more or less timbered, are consecrated to the culture—of prunes. Undisturbed nature is still accessible, nearer at hand in that golden west than in the green middle west or on the Atlantic slope. Even the tourist can reach it if he will; not in Yosemite with its hotel, camps, and mule-polluted trails; but beyond, at the top of the world, in the higher places of the Sierra.

Civilization in the form of agriculture plays sad havoc with natural native vegetation, destroying, driving back, exterminating most, domesticating and assimilating few, plants.

Where agriculture has not yet reached, the lumberman hews down that man may elsewhere build up. There is, so far as I know, only one of our forests which, given a fair chance, will quickly reproduce itself. The redwood forest which used to stretch for hundreds of miles unbroken over the eastward as well as the westward slopes of the mountains closely paralleling the coast line of California, can reproduce itself and does wherever the lumberman fails to clear by the cheap and costly means of fire. The redwood suckers like a lilac, a rare quality in conifers. If the underground parts of a felled tree are left alive, suckers will spring up, and by their astonishingly rapid growth, almost throughout the twelve month, drenched in life-giving fogs in the rainless summer and checked only by the coldest weather of the mild and rainy winter, they will yield a stand which in thirty years will be merchantable timber. Meantime the soil is held in place, the wash is slow and comparatively harmless, the streams are clear, and those turbid destructive floods so common elsewhere, are almost unknown.

The vast areas which the nation has saved from the lumberman to furnish timber for our children and their children, to cover the watersheds and to conserve and control the yearly run-off, are annually placed in jeopardy by the railroads. Last year, disastrous fires in the far northwest, and the less extensive fires of Wisconsin and Minnesota in the summer preceding, only too plainly showed this. So dreadful has been the loss of human life and of property from this cause that the substitution of sparkless fuel-oil on locomotives traversing forested areas is now not only urged by the forest service, but being seriously considered by the railway companies. Until electric traction or sparkless fuel is employed, each dry season will bring its record of destruction along the tracks of civilization through forest and grazing land.

Reaching almost as far from its source as the fires accidentally set by civilization, is the destruction of vegetation by certain forms of industry. The damage is done in two ways, by drainage and by fumes. The composition of ordinary domestic drainage is disturbing enough to vegetation. I have had occasion to notice this along the shore of Monterey Bay. When I first saw these waters they were bordered on one side by the towns of Monterey and Pacific Grove, sleeping peacefully, the one after a somewhat turbulent past, the other on federal and denominational pensions. Between tide marks and further out were a fauna and flora so rich and so varied that a few years earlier, when the whole coast of California was open for such a choice, this had been selected as the best location for the Marine Biological Laboratory of Stanford University. So far as I can see, the fauna and flora are as rich to-day as then, but with the recent rapid increase in population of these two towns and the consequent increase in sewage pouring into the bay at no great distance below low-tide mark, there has been a decided increase in the quantity of diatoms living attached to the seaweeds growing between tide marks. The body of water in Monterey Bay is so very large and so thoroughly mixed by the tides, and the volume of sewage discharged into it from the towns on its shores is still so small in comparison, that the sea-water, even now, deserves to be called pure. But it is no longer perfect purity. Its increasing though still relatively slight pollution is shown by the change in the balance of the population between tide marks, by indicators exceeding in sensitiveness those of the chemical laboratory, by living things. We all know that, when pollution goes further, certain plants are no longer found in stream and bay; river and mud-flat become huge cultures in which coarse algæ and offensive bacteria flourish.

In all such changes as these, however, there is only a change, not a decrease in the value of the water as a nutrient solution. Nothing poisonous has been added to it, only substances which so abundantly nourish bacteria, blue-green algæ, diatoms and coarse green algæ, that other forms become more or less crowded out. This is so common an effect of civilization on vegetation that we think nothing of it. On the other hand, the actual poisoning of plants and animals by drainage from industrial establishments attracts much more attention and in many states is forbidden by law. When there are no longer trout in a once famous fishing stream people are much more likely to notice and to remedy the injury than if sawdust or tailings merely make the stream and its borders unsightly or desolate. In the parts of the west dependent upon irrigation, drainage from mines or works which makes the water poisonous to the crops, arouses the public much more than the pollution which makes it dangerous to drink.

Perhaps it is but natural, and only another exhibition of that modesty which constitutes the distinguishing characteristic of the human species, at all events those influences which affect man and other animals are more likely to be recognized by him than those which affect plants; and those which affect his quick-growing crops, with their more frequent money returns, are more promptly recognized than those which may greatly augment or diminish a harvest coming only twice or thrice in a century. What do we know of the effects of illuminating gas in our houses and gardens, of the effects of the gaseous emanations from domestic and factory fires upon the trees of streets and parks? The only reason why gas-piping is no worse, is that greater leakage would be unprofitable to the gas companies, even at the present high rates. As it is, our houses and laboratories reek of gas to the sensitive nostril, and garden and green-house yield less than they would if the soil were not traversed by badly jointed pipes.

We think and speak of the smoke nuisance as if it were merely a soot nuisance. We do not realize that the most perfect and ideal "smoke consumer," which would certainly lessen our laundry bills, would utterly fail to lengthen life. The most perfect fuels, because the least injurious, are wood and alcohol. How often have we seen a farmhouse overtopped by some great tree and through its branches the fragrant wood-smoke floating gently from the chimney. The substitution of coal for wood would be quickly followed by a succession of troubles which would finally kill the tree, not by "closing its pores" with soot, but by poisoning the living cells in leaves and branches by the sulphur and chlorine fumes given off in burning the coal. So in our towns, you may see holes in what should be domes of foliage, bits of sky through what should be hollow masses of translucent green, olives and yellows when there should be a brilliant verdure. More careful examination will show that not only is the foliage deficient in amount and defective in color in carefully tended city trees, but their annual growth in length and thickness is less than that of their fellows uncared for in the purer air beyond the outmost suburbs. The much advertised "tree surgery" of to-day is a species of not altogether useless quackery, developed to treat a symptom in communities which do not yet recognize and remove the cause of disease. Between gas in the soil and gases in the air urban trees lead a more or less poisoned and morbid existence, appreciated and enjoyed only by those who can not or will not go where trees grow rapidly and well, solitary or gregarious, according to their kinds, a delight to the eye, an inspiration to the spirit, a shelter to the birds, and a satisfaction to the lumberman.

Perhaps this seems an exaggerated statement of urban conditions, but an examination of the trees in the parks of Pittsburgh, Cincinnati, St. Louis and Chicago, among the industrial cities using mainly soft coal, and of New York and Boston, in which hard coal is the principal fuel, will convince the fair-minded observer that something is wrong.

Air and soil analyses and experiments under controllable conditions, will alone reveal the cause of the condition of urban trees and of those growing near industrial plants from which poisonous fumes emanate. Such analyses of air and soil can be made only by a skilled chemist, and such experiments should be attempted only when a skilled chemist and a trained biologist can cooperate under such conditions of climate and equipment as to justify the expenditure of time and money.

In the remarkably pure air of Stanford University, with the nearest domestic coal fire a quarter mile away and with gas supplied to the university by a single small main, a greenhouse has been so constructed that it is completely divided into two exactly similar halves, in which experiments and their controls can be carried on under as nearly natural conditions as can be conceived. In each half of this house there were boxes of growing grain, a considerable variety of potted seedling trees, one, two and three years old, and other plants, aquatic and terrestrial. The grain was grown on the spot from seeds; the trees were grown from the seed in the pots and were brought into the house so long before they were used in experiments, that they were quite accustomed to their surroundings. Into one half of the experiment house, a dose of sulphur dioxide equal to the proportion in pure city air, was introduced daily (Sundays excepted) for months, during the resting period only for one set of trees, during the growing period only of another set, and during the resting and most of the growing period of a third set.

The trees continuously in the side of the house dosed daily with a very minute quantity of sulphur dioxide gas, blown into and thoroughly mixed with the air of the house, showed a growth in length two thirds of that of the trees in the pure air of the other half of the house. There are no visible injuries; only measurement shows that those trees in air purer than that of most cities do not thrive, do not make as much growth as trees in thoroughly pure air. Analyses show that the sulphur dioxide is fixed, mainly in the leaves, and thus disturbs the vital activities of plants. The results with grain correspond. These results obtained by experiment justify, therefore, the assertion that the problem of urban smoke is one of gases as well as solids, of poisonous fumes as well as inconvenient soot.

Turning now from cities, in which the growth of plants is purely for pleasure, and by no means natural or commercially profitable, we may ask what are the effects of smelting and other works from which poisonous fumes may be discharged?

Manufactories of certain chemicals, or of materials in the preparation of which poisonous substances may be volatilized, and establishments in which sulphurous ores are roasted either for the extraction of the metal or in order to obtain sulphur for the preparation of sulphuric acid, will affect surrounding vegetation more or less seriously. Even locomotive smoke injures the plants along the railroads, as anyone may observe. The herbaceous plants along the track, but quite beyond the reach of steam, often show burned spots on their leaves and stems. These are acid burns due to the fumes, of sulphur principally, discharged from the smoke-stacks of passing engines. One seldom travels over an old railway through woods or forests in which there are not many trees close to the line with branches or tops dead. Often the immediate cause of death is insects or fungi or possibly bacteria; just as tuberculosis may be the immediate cause of death in factory workers debilitated by long hours of labor under conditions unfavorable to robust health. But in many cases, locomotive smoke can be shown to be the immediate as well as the mediate cause of damage or death to trees along a railroad.

Such cases as these are, however, as unimportant, except as showing a principle, as they are at present unavoidable. On the other hand, where the prosecution of one industry results in the injury of many others, in the destruction of property, public as well as private, and in such changes in the run-off that the flow of water in streams perhaps hundreds of miles away is affected, the question becomes one of great importance. An illustration of this is found in the southeast corner of Tennessee, where, for many years, a low-grade copper ore, rich in sulphur, has been smelted. There are now two smelters in that region. The country is mountainous, the slopes naturally covered with the large-leaved mixed forest of the southern Appalachians, well watered by the frequent summer rains. The virgin forest was long ago cut for mine-timbers and for fuel in that extensive district known as Ducktown, but the second growth is also gone and, up to three years ago, nothing of any value could be cultivated within a distance of miles from these smelters. In the suit won by the state of Georgia before the Supreme Court of the United States, it was shown that the poisonous effects of the fumes were visible in Georgia at a distance of forty miles from these Tennessee smelters. Three and a half years ago, so hopeless was the condition of the people attempting to farm there, that they declared even the soil was poisoned, a mistake, of course. Since there is scarcely any level land in that district, one may imagine the result of removing the forest cover, destroying the undergrowth and preventing any other vegetation which might cover the naked soil with its branches or leaves and hold it together and in place with its roots. Instead, the leaf-mold accumulated during centuries on the forest floor and the fine soil worked and re-worked by roots, worms and other occupants of the ground, were quickly washed down the slopes into the turbid streams, floods took the place of the spring freshets, and the bare earth battered by the rains constantly gave its fertility to the already rich lowlands far away, or to the still more distant and unneeding sea.

Conditions are better now. Instead of throwing away as a poisonous waste the sulphur dioxide formed in smelting their ores, the smelters are now collecting as large a proportion of this gas as possible for the manufacture of sulphuric acid. This they sell to the manufacturers of phosphate fertilizer. Instruction is leading to improved methods of farming, to the use of the phosphates made from converted smelter waste, the farms are beginning to yield crops which repay tillage, and the woodlands are improving. To complete this romance of industry reformed under federal compulsion, it need only be said that the manufacture of sulphuric acid is so profitable that the smelters would be run for that purpose now if for no other, and that their copper costs them nothing!

In this conflict of industry with agriculture and the native vegetation the outcome has been a happy one; for industry, forced to recognize prior and more general rights, has been so modified as to eliminate its injurious effects and to enhance its own profits. This is seldom possible to anything like the same extent. The greater the industrial plant requiring reform, the more intense and extensive the damage it does, and the greater must be the difficulty of making the needed changes in method of operation. And yet even manufacturers are coming to see, by compulsion to be sure in most cases, that their rights are not unlimited, that they must conduct their business in such a manner that agricultural or other legitimate and established interests will not suffer and that the property of the nation be not injured.

This is the significance of the agreement reported in the newspapers as recently made by the Attorney General of the United States with the owners of the great smelters in Montana. These smeltermen, rather than fight a suit brought in the federal court by the Attorney General, have promised to modify their methods of extracting copper and the other metals from their ores, so that they will no longer injure the property of the nation. One of these smelters handles 10,000 tons of ore per day, when running to its capacity, and last summer I drove twenty-five miles away from it, passing over the continental divide, before reaching apparently sound uninjured forest. Such has been the widespread damage by one industrial plant in the ten years of its existence. The national forests at the headwaters of the Missouri and the Columbia are dying, and the Attorney General, in compelling their protection by reform in the extraction of copper, has done his duty well.

Another case in point is afforded by a recent decision in southern California. In the heart of the orange-producing region of the San Bernardino valley, the manufacture of cement, begun on a small scale, has developed to considerable proportions. Going eastward on the Southern Pacific Railroad from Los Angeles, one passes through almost continuous groves of orange trees, their dark green leaves glistening in the brilliant sunshine which has given that land its name. Suddenly one notices that the foliage is no longer green, but gray, not glossy but dull, and that on the opposite side of the train is a cement works constantly wasting part of its laboriously manufactured product. This dust settles on leaves and soil, enters houses, and becomes a nuisance everywhere. It sets wherever there is moisture, in dew or fog or rain, and does not wash off like ordinary dust. By reason of this opaque coating over the leaves, the manufacture of food in these green organs is interfered with, and the insufficiently nourished trees yield a correspondingly diminished crop. So serious has this injury to the orange industry become, that the court has decided that the manufacture of cement in one plant must be stopped entirely, and in another may be carried on only on a small scale, until such changes have been made that manufacture can be resumed without disadvantage to the orange-growers. That such changes will be made in this plant I have no doubt.

Such cases as this, revealing the conflict of civilization and vegetation, decided with wisdom as well as justice, leading to improved methods of manufacture, go far toward establishing that new balance which must be attained in America, as it was reached long ago in more populous Europe, that balance between civilization and vegetation which will ensure the stability and the prosperity of both.

ENGLISH AS AN INTERNATIONAL LANGUAGE

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OF our thousand languages, great and small, dead and living, natural and artificial, from Edenese to Esperanto, which is to be the world-speech of the future? "Why, English, of course!" America replies with one mighty voice, in which rings the indomitable optimism of the nation. Now, I love English dearly, for having spent twelve years of my youth in trying to master some of its intricacies; I love America still more, for her generous hospitality, which I am at present enjoying, and yet I find myself unable to join in the chorus so ably led by Professor Brander Matthews. I do not believe that English is destined to be the international language of to-morrow. On this side of the Atlantic, this may sound paradoxical; across the water, it is accepted as a truism, even in England. Let us suppose ourselves in a neutral zone, and examine judicially the pros and cons of the case.

Faith in the future supremacy of English can certainly not be lightly dismissed as a mere chauvinistic delusion. It is based on personal experience: we all know how eagerly the better class of immigrants take up the study of the language; how impatient their children are of any other tongue; we know that, with nothing but English and money at our command, we can be understood, and respectfully fleeced, in all the best hotels in the world. Statistics give scientific support to these individual impressions. One half of the world's commerce, two thirds of its shippping, one fourth of its population, one half of its railroads, of its newspapers, of its postal transactions, are under the control of the English-speaking countries. Grammatical and literary arguments can then be brought forward in favor of English: its grammar actually simpler in some respects than that of Esperanto, its international quality as a strongly Romanized Teutonic language, its wonderful vocabulary which can be extended in all directions without losing its unity, the unrivaled freedom of its syntax, which enables it to use the same word as a noun, a verb, an adjective or a preposition; last but not least, its unbroken literary record, and myriad-souled Shakespeare as supreme argument.

All this has to be granted, and is granted without reluctance. No one denies that English is one of the three or four world-languages, and a prince among its peers. But that it will ever attain the unique position once held by Greek, Latin or French does not by any means follow.

There are three ways for a language to achieve universality: political domination, natural development, international agreement. It was through the political domination of Rome that Latin spread over the whole of the ancient world. It is through the same agency that English was and is diffused in Ireland, India and the Philippines; French in Languedoc, Provence, Brittany, Flanders and the colonies; German in Slesvig, Poland and Lorraine. Should England and America conquer the world, or simply control the world, English would become everywhere what it is in India: the language of government, modern culture and commerce.

It can not be denied that the British Empire alone is larger, richer, more varied, more powerful, than Rome ever was under Augustus or Trajan. But Rome stood as practically the sole representative of civilization: side by side with the Anglo-Saxon world there are other worlds —Germanic, Slavonic, Latin and Mongolian, hardly inferior in material development, and in some respects fully equal in culture. That the fate of Carthage and Greece awaits France and Germany can not be suggested, except in jest. Ten or twelve years ago, conditions were different. Anglo-Saxondom was a religion—hardly less aggressive than Islam under Mohammed; Rhodes and Rudyard Kipling were its prophets. China, South America, the colonies of Portugal, Holland and France were to be turned into Anglo-Saxon dependencies. Sometimes Germany was bidden to the feast, as a poor relation, and the London *Daily Mail* published highly sensational maps of the coming partitions. Where are the dreams of yestereve? The threatened nations have prospered unimpeded; other claimants to world-wide influence have come and gone for a season, like Russia—or come to stay, like Japan. The acknowledged weakness of Anglo-Saxondom in land forces has had a wonderful sobering effect, and, more than anything else, the growing sense of international justice, the thorough sanity of Great Britain and the United States, have contributed to dispel those unholy fancies.

Besides, linguistic domination does not always follow political domination, unless there be an overwhelming disparity of forces, material and moral, between the ruling people and their subjects. The Tagals will learn English and the Malagasy French, but it is more than doubtful that Mexico, conquered by the States, would learn the language of their victors. The willingness with which immigrants adopt English must not mislead us. Numerous as they are, they are, at any given moment, a minority. They come unorganized, severed from their traditions, into a highly civilized country with a strong national feeling. Yet, the point of saturation might soon be reached. Wherever in the British Empire the non-English elements are compact and have a tradition back of them, they maintain their language with curious pertinacity, like the Boers and the Habitants. Even the French in Louisiana, although they were but a handful, have not yet been fully assimilated. Greek profited at least as much as Latin by the Roman conquest of the world. After a century of union with the Empire of the Tsars, the best educated inhabitants of Finland learn German rather than Russian. Magyar, Czech and Polish have triumphantly asserted themselves against German, once the only official language in the Hapsburg dominions. After forty years of strenuous endeavor, the German Empire has not shaken the hold of French culture in the essentially Teutonic province of Alsace. When one hears of the incessant struggle in Germany, Austria-Hungary and Russia, caused by the attempt of imposing a language on a conquered people, one can not but hope that England and America will be wise and generous enough not to commit the same mistake—or the same crime.

Without any coercion, the natural superiority of a language, or of the civilization which it represents, will ensure its triumph. Thus Cornish disappeared and Welsh is receding before English; thus, for a time, and without any political connection between the two countries, Rumanian was entirely overshadowed by French. By a process of natural selection, some languages remain provincial, like Basque or Breton; some become national, like Hungarian; and a few conquer international status. Among these, by a similar process, one will forge ahead of all others and become alone international: such is the destiny claimed for English.

All this is theory: do facts point the same way? It seems that every year we have more claimants instead of fewer to national and international rank. A century ago, French was alone in the field. At present, not only French, German and English, but Italian enjoys in all international activities a sort of official recognition. And how long will Spanish and Russian be content to lag behind? The distinction made by H. G. Wells between the three "agglomerative" languages, French, English and German, and all the rest, is by no means so clear as he would have us believe. There is a long way between English and Catalonian, for instance: but all the links of a continuous chain could be found. Can we consider as a minor language Italian, with its magnificent literature, past and present, its active scholarship, its intrinsic beauty, its faith in its own destiny?[1] Or Russian, or Spanish, with their vast numbers, their great achievements, their boundless possibilities? The strong plea of the Brazilian delegate at the Hague Conference against the notion of secondary powers not entitled to all the honors and privileges enjoyed by a few applies with even greater force to the notion of secondary languages. Language has become such a symbol of racial patriotism that the balance of power is preserved as jealously in the linguistic domain as in the political.

[1] Cf. the activity of the Dante Alighieri Society for the spread of the Italian language.

The present supremacy of English in commerce is undoubted. Yet it does not amount to a monopoly. English has to face the rivalry of German in central and eastern Europe, of French in the Mediterranean countries, of Spanish in South America, of the native languages everywhere. When the commercial hegemony of England was absolute and apparently indestructible, England could impose the use of her language to all her customers. German competition has taught her that it paid to use the customers' own speech. The unique position of English is thus becoming a thing of the past. England and the United States may retain their lead and even increase it, but the days of monopoly are gone.

All things related to traveling—hotels, traveling agencies, navigation companies, were long the stronghold of Anglo-Saxon influence. But there is no sign that the *relative* importance of that influence is on the increase. A generation ago, only Englishmen and Americans had both the means and the desire to travel. The French were "casaniers" (stay-at-home); the Germans were poor, and all the rest, especially the South American "rastaquouères," were totally without prestige. The number of Anglo-Saxon tourists has greatly multiplied. Instead of limiting themselves to a few well-known resorts, they haunt every little corner in Europe. But they are no longer alone. German and French cruising yachts call at every port. Parisian hotels can not be content with the "English spoken" of yesterday. He who pays the pipers calls the tune, and we are beginning to hear other tunes besides "Rule Britannia" and "My Country, 'Tis of Thee."

We do not believe that any nation is going to wrest from England and America the scepter of the commercial world; we do not believe that Anglo-Saxon influence in that domain is on the wane. But we do believe that it is not likely to become greater than it was some ten years ago. And, since it was not sufficient then to secure the adoption of English as international medium, it probably never will.

Business is not the whole of life. If we turn to science, we find that, whilst English has conquered international recognition in practically all branches of learning, in hardly any does it rank first. England and America have as splendid a roll of scientists to show as Germany or France; but many of these were isolated men of genius. Germany has a larger host of conscientious, subordinate scientific workers and a larger *competent* public. The lead of Germany is probably not so considerable as some Americans are apt to think. This country has long been a province of the Fatherland as far as higher education was concerned, and it retains to the present day a pro-German bias which makes it unjust to the achievements of England, France, Italy, and even to its own. But, great or small, that lead, from the linguistic point of view at least, is undeniable. For the purpose of disinterested study, every scholar and scientist in the world has to learn German first, and possibly French second. In this connection, again, the claims of Italian are too often disregarded in America, and yet there is hardly any branch of learning in which Italy is not doing excellent work. We had occasion, this year, in an English-speaking university, to use the Italian translation of a Danish work on the old French epic. This is a small but typical instance of the growing cosmopolitanism of science, and of the usefulness of Italian.

But, in the world of science just as in the world of commerce, the so-called minor languages show an increasing tendency not to recognize the privilege of the three or four now in possession. Berthelot complained that, whilst in his youth, with four modern languages *only* at his command, he could keep in touch with scientific activity everywhere, he could no longer do so at the dawn of the twentieth century. Science does not quite obliterate national susceptibility. Scientists work for their compatriots primarily. Perhaps they shirk the effort which the use of a foreign tongue always involves; perhaps they are afraid of the traps which the grammar of French, English or German is fenced round with, and in which even the wary may fall. Scandinavian, Dutch and Slavonic scientists still use the recognized world-languages occasionally in preference to their own; but there is a growing body of untranslated and often valuable works in Dutch, Danish, Swedish, Russian. The unification of scientific literature under German hegemony is fast becoming a dream, and English hegemony the shadow of a dream.

The position held by English in commerce, by German in science, belongs to French in the world of "polite culture"—diplomacy, society, art and letters. It is a well-known fact that this position is not what it used to be. William II. is an accomplished French scholar and an admirer of Frederick the Great; yet he does not cultivate the tongue of Anatole France as his ancestor that of Voltaire. The Gallophobia of twenty years ago no longer blinds Berlin to the merits of France, yet the Prussian Academy would not as in 1784 crown a modern Rivarol for an essay on the universality of the French language. There has been, almost everywhere, a sharp and often unjust reaction against French influence. The Belgian Flamingants have revived their neglected dialect, and secured for it absolute equality with French. In Rumania, where the Frenchification of the upper classes had gone to almost incredible lengths and was threatening to stifle the legitimate development of national culture, there have been actual riots against the "Bonjouristes." And the predominance of French in the Mediterranean is not so exclusive as it once was.

However, the position of French is much stronger than most Americans believe. America welcomes our lecturers, our actors; few colleges are without a French club, and even in small towns, ladies will meet once or twice a month "pour parler Français." Yet, we regret to say that America, for whom we fought, America, our sister republic, is, of all great nations, the most indifferent to French culture. The small number of Frenchmen in this country, the bad reputation of a few international places of amusement in Paris—some under English management—a small, noisy literature exclusively for the Boulevards and the export trade, perhaps also the enormous influence of Germany, whose friendliness to France was none of the warmest—all these factors have led many Americans to neglect France, her people and her language. America was, I believe, the first great nation to restrict the use of French as the diplomatic language, and she is perhaps the only one at the present day where more students learn German than French.

However, in the rest of the world—for there *is* a rest of the world—French maintains its position. It is curious to notice that foreigners are much more sanguine than the French themselves about its future. At the Liège congress for the diffusion of the French language, a Russian, Novicow, led the optimists, against our great medieval philologist, Paul Meyer, probably lost in his regrets for the glorious thirteenth century. Rivarol was never more complimentary to us than H. G. Wells, Gubernatis, Valera or Max Nordau.

Professor Brander Matthews believes that the larger intellectual and financial opportunities of English will lure ambitious writers away from their language and their people. He gives Maarten Maartens as an example. This tendency is not new, and French, in the past, could point with pride to many such transfuges, from Brunetto Latini to Frederic of Prussia. And that power of attraction is not spent. For anything except a sensational novel or a volume of sermons, French offers at least as good financial opportunities as English, a more independent and better trained body of critics, a more open-minded, more discriminating reading public. That is why, not only in the days of Chaucer and in the days of Gibbon, but in this twentieth century of ours, so many foreign authors have adopted French as their vehicle. And not only critics and novelists, but poets—which supposes an extraordinary degree of familiarity with the language: Belgians of Teutonic origin, like Verhaeren, Maeterlinck, Rodenbach; Rumanians, like Bolinteano, Hasdeu, Macedonsky, Stourdza, Helen Vacaresco; Greeks like Parodi and Papadiamantopoulos (Jean Moreas); the Cuban Jose-Maria de Heredia, perhaps the greatest of them all; English poets—Swinburne, Oscar Wilde, Mary Robinson (Mme. Darmesteter-Duclaux); finally true-born Americans—Francis Viele-Griffin from Virginia, Stuart Merrill from Long Island, both doing excellent work:

> . . . J'en passe, et des meilleurs!
> Pour trois qui vous viendraient, il m'en viendrait soixante.

I do not mean to say that French is, or will be, in any but the vaguest sense of the term, the international language of literature. If a few writers may be led by the prospect of more rapid success, or merely for personal reasons, to serve under foreign colors, the majority will remain faithful to their mother tongue, great or small, for in it alone their best work can be done. A language spoken by five million men may be as good a literary medium as one used by a hundred and twenty million. Indeed, a Pole, for instance, might actually be better off than a Frenchman in many respects, for he would combine an intenser national feeling with a more cosmopolitan culture. It is possible not only to do good work in the so-called minor languages—most of which have a larger public than English in Shakespeare's time—but also to conquer universal fame. Russian is little known beyond its frontiers, yet Tolstoy is everywhere admired. New York alone has a much larger population than Norway, but Clyde Fitch's glory has not eclipsed Ibsen's. Sienkiewicz's country is dismembered, his language persecuted in Prussia and in Russia—and who has not read "Quo Vadis"? Mistral writes in a dialect, a patois, an artificial one at that, the combined work of the peasant and of the philologist; no one was surprised when the Nobel prize was awarded him. We do not see any tendency to a concentration of languages analogous to the Marxian concentration of wealth. But if there were any signs of such a concentration, they would seem to be in favor of French rather than English.

It seems therefore improbable that this tangled problem of international speech will be solved automatically, by a natural process of selection. One alternative remains to be considered: a universal agreement. There is a growing spirit of cooperation among nations, and so the adoption of a world-language is becoming at the same time easier and more desirable as time goes on. Latin was universal when there was a Roman world, Imperial or Catholic; classical French was universal when there was a "classical Europe"; after a century of division, the world is recovering the consciousness of its unity. Let us hope that a conference will be called together, and a universal agreement arrived at; what, in an open competition of that sort, would be the chances of English?

I waive the argument from the present erratic spelling of English. Professor Brander Matthews is doing his best to reform it. Let us hope he will fully succeed, that is to say, that English will be altered beyond recognition. Perhaps the difficult sounds of the language, its weird consonants, its tripthongized vowels, might also be eliminated. The present chaotic state of English accentuation calls for urgent reform. A "Simplified Pronunciation Board" would help us out, by making it a misdemeanor to pronounce English otherwise than in the scientific, or German, way. After such thorough overhauling, English would stand a little ahead of French, and not too far behind Spanish, Italian or German in the way of logic and simplicity. But all that trouble would be vain—a tremendous trouble, since it would oblige the Anglo-Saxon world to learn its language anew. The qualities of English, not its defects, are the main obstacles to its adoption.

The *raciness* of English is its glory and its bane. There is no more strongly individualized language. On account of the very simplicity of its grammar, of its syntactical flexibility, it has more idioms, and is more puzzling to foreign minds, than either German or French. English is an admirable tool, plain, strong and sharp, singularly dangerous in unskilled hands.

The might of the English-speaking countries would be the next objection. The balance of power would seem to be destroyed in their favor. Germany could agree to the selection of Italian without loss of self-respect, or even to that of French, because there are, for the adoption of French, historical reasons which, at present, do not wound the susceptibilities even of the most sensitive nation. But to accept English would be to acknowledge one's own inferiority. The boastful tone of certain writers and orators, although that is fast becoming a thing of the past, greatly increases the moral force of this objection.

Finally, the English-speaking race is progressive, but on its own traditional lines; its literature is deeply human, but intensely national in its expression. The abstract, analytical character of classical French, the effort to describe "man in general," and to discover truths of immediate and universal application, are lacking in English. To this fortunate lack, English literature owes much of its depth and freshness, English thought its "congruency with the unutterable," English political life its wise compromises, its freedom from revolutions and adventures. French is essentially international. Patriotism has inspired French writers to compose admirable poems, and Chauvinism is, or used to be until quite recently, as rife in Paris as Jingoism in London. Yet the French language can be so completely dissociated from the French nation that the most abundant and the bitterest denunciations of France are written in French.

Once more, I hold no brief for French. I do not believe that it will ever be more fully recognized as international than it is at present. There are strong reasons in its favor, but none is decisive. And there are two great objections against it. It is the language of one of the world-powers, and international jealousy would prevent its adoption. Then its strongest claims are historical: but the new nations, America, Japan, quietly ignore European history. A tradition is not a reason; it loses all its virtue as soon as it is no longer respected. America refuses to be ruled by the shade of Louis XIV. We can not blame her. And I must say that, as a Frenchman, I do not regret it.

For our own experience in the eigthteenth century has taught us that universality is a mixed blessing, perhaps a curse in disguise. As everything must be sacrificed to perspicuity and simplicity, there is a danger of enfeebling the language, of making it colorless. It breeds self-satisfaction, and, by making the study of other languages less useful, it favors ignorance and one-sidedness. For many years, the French smiled contemptuously at whatever was not French. They are at present reacting almost too vigorously against that tendency; let us hope that England and America will escape both these dangers. The assumption of superiority on the part of one language and therefore of one race, of one or two nations, causes jealousy, diffidence, hatred. France had to pay a heavy price for her once exalted position. She had to convince the world that she was not in any way a menace before sympathy would flow back to her.

The present situation, with the curse of Babel still on our heads, is not, of course, incompatible with progress, national and international. With the diffusion of the study of modern languages, with the multiplication of translations—some famous works have appeared simultaneously in eleven tongues—with the growing international vocabulary of science, commerce and pleasure, the world feels more and more its essential unity. We can live and prosper without an international language; but, in the same way, we could have lived and prospered without the printing press, the railroads and the telegraph.

The problem remains with us, baffling and entrancing. We all realize what a progress it would mean if all conventions, societies, publications of world-wide scope, would adopt one world-wide language; if not diplomatists, scientists and scholars alone, but the business man, the social worker, the missionary, even the common laborer, had a simple, universal means of intercommunication.

We have attempted to show that through neither conquest, natural development or international agreement had any living language a serious chance of being accepted as international. But is there no other solution? Are we not substituting, in every domain, order for chaos, science for tradition, the organizing will of man for the blind arrangements of fate? Is it beyond the capacity of our scholars to select or in the last resort to devise, a perfectly neutral tongue? If French or English will not do, why not try Esperanto?

PERFECT FLOWERS IN MAIZE

By Professor E. G. MONTGOMERY
UNIVERSITY OF NEBRASKA

IN The Popular Science Monthly of January, 1906, the author wrote a brief article entitled, "What is an Ear of Corn," presenting some observations on the occurrence of hermaphrodite flowers in maize; this occurrence with other evidence indicating that maize had probably originated in some manner from a perfect flowered plant, while in all cultivated maize the flowers are strictly single, being either male or female. However, a comparative study of male flowers (from the tassel) and female flowers (from the ear) showed analogous parts in both. The tassel flowers in the older stages, however, are borne in pairs, while the ear flowers are single, but a study of the embryonic ears showed the male flowers to be twinned at this stage, but as development took place one of these flowers became entirely abortive and only one fully developed. Perfect flowers were also found in somewhat deformed plants, which looked in many ways like reversion in types. A study of the gross structure of the ear and tassel showed a close structural analogy between the ear (including cob)

Fig. 1. Hermaphrodite Flower of Maize (*Zea mays*) showing structural features (reproduced from former article).

Fig. 2. Ears of Maize bearing perfect Flowers. These ears are quite young, *i. e.*, just in blossom. The mature ears averaged about six inches in length. Practically all ears of this strain came true to type.

FIG. 3. THE UNUSUAL TYPE OF PLANT, producing ears in Fig. 2, and which seem to be associated with the production of hermaphrodite flowers in maize.

and the central spike of the tassel, and strong evidence was found in support of the theory that the ear was a development from the central spike of the tassel borne on a lateral branch of the plant, the other branches of this tassel becoming abortive. Good examples were found of ears, showing remnants of these lateral tassel branches, confirming the above statements. At that time the author had only observed the perfect flowers in the very young stages of development and on more or less deformed plants. Fig. 1 is reproduced from the article referred to, indicating the character of these flowers.

Since then, types of corn showing this hermaphrodite flower on normal types of ears have been observed. Fig. 2 is an illustration of such an ear.[1] Some thirty plants of this were grown and all came true

[1] The seed of this was secured from Mr. C. P. Hartley, Department of Agriculture, Washington, D. C., who discovered the plant as a reversion in one of his breeding plats.

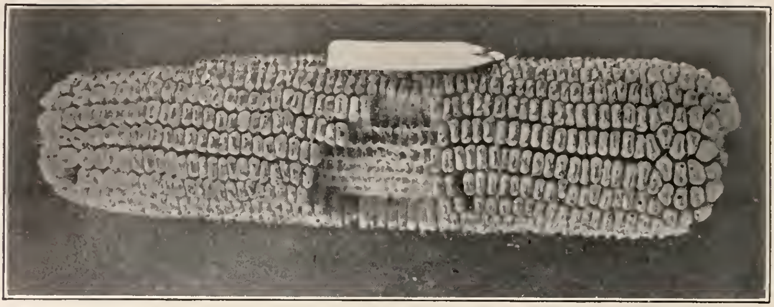

Fig. 4. Ear of Boone County White Dent Maize, with perfect flowers. The ear was a very fine specimen.

to type. The ear was about six to eight inches in length and of normal appearance, except that each seed had three fully developed stamens, arising from near the base. The plant, however, was very peculiar in appearance, as shown in Fig. 3. The plants were about five feet in height, the stem short jointed, with broad leathery leaves, resembling tobacco plants as much as corn plants. Professor Emerson, of this station, has had hermaphrodite plants occur in several of his corn hybrids and in all cases they have had this peculiar type of foliage. If this type should be a reversion toward the primitive type it would be of great interest, since we have no grass plant at present having this appearance.

Fig. 5. Cross-section of Ear in Fig. 4, showing stamens at near base of kernels. Practically every kernel had three well-developed stamens.

Another most interesting ear of perfect flowers was found by chance in a lot of Boone County White Corn, secured from a prominent grower. This variety represents the highest development in modern improved corn. The ear in question was unusually large and well developed, as shown by Fig. 4, the ear weighing about 16 ounces. Fig. 5 is a cross-section of the same, showing the presence of stamens with every kernel. Fig. 6 is an enlarged photograph showing both sides of one kernel. On the anterior side are shown three well-developed stamens. On the posterior side, at the very tip and practically embedded in the cob, are three small stamens. These are the last remnants

FIG. 6. SHOWING BOTH SIDES OF KERNEL, FROM EAR IN FIG. 4. Three well-developed stamens shown on posterior side. On the anterior side and embedded in the cob were three rudimentary stamens, remnants of the abortive flower.

of the abortive flower, described in the former article referred to. This little abortive flower can only be found in the early embryonic stages of development, and usually all trace of its presence is lost except the extra pair of glumes on the posterior side of the kernel. These little stamens, however, indicate that at one time it might have functioned and give us another clue to some of the evolutionary changes that this interesting plant may have gone through.

THE SOUNDS OF "CH" AND "J"

By WINIFRED SCRIPTURE
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THE sounds "ch" and "j," as in "church" and "judge," have been represented, on the one hand, as being composed of two sounds, "t" or "d" with "sh" (in phonetic transcription *ts* and *dz*) and on the other as being single sounds (in phonetic transcription *č* and J). Related to this is the question whether the Italian "c" and "g" before "i" or "e," as in "cio" and "gia," are more like "ch" and "j" or like the two forms of "sh."

Records of these sounds were made with a voice-recording apparatus (Fig. 1). This apparatus consists of a mouthpiece into which the words are spoken. The waves thus formed proceed down a tube to a rubber membrane at the end, making it vibrate. A straw lever is attached to the membrane with which it rises and falls in unison and so makes a record on a surface of smoked paper around a revolving cylinder.

Records of typical pronunciations of "ch" and "j" enable us to settle their nature definitely.

FIG. 1. RECORDING THE VOICE. The waves from the mouth proceed down the wide tube to the rubber membrane at the end. The vibrations of the membrane are recorded by a straw lever on a surface of smoked paper around a revolving cylinder.

A record for "Mitchell" is shown in Fig. 2. It begins with very faint vibrations for "m"; thereupon follow strong vibrations for the vowel "i." The straight line after the vowel indicates a complete stoppage of breath, that is, the sound is an occlusive. After the occlusion the line rises at first gently and then strongly, as the result of the stoppage being ended and the air rushing out rapidly; this phenomenon is called an explosion. The sound at this point is therefore an occlusive with an explosion. This is the sound "ch" which is indicated by the spelling "tch" in the word recorded. The word ends with strong vibrations for the vowel "e" and fainter ones for "l."

A record of the word "nut" by the same speaker is shown in Fig. 3. It begins with very faint vibrations for "n" followed by stronger ones for "u." The straight line indicates the occlusion for the "t." The strong sharp rise of the line indicates that the "t" ends with a sharp explosion. This explosion is quite different from the more gradual explosion of "ch" as shown in Fig. 2.

A record of the word "nutshell" by the same speaker is shown in Fig. 4. Very faint vibrations for "n" are followed by stronger ones for "u." The straight line indicating the occlusion of the "t" is followed by a very gradually rising line which remains for a time at quite a distance above the base line. This indicates that the occlusion of the "t" was not followed by an explosion, but by a continuous rush of air. This portion of the record is typical of the records for "sh."

A record of final "ch" in the word "atch" is shown in Fig. 5, a record of initial "ch" in "chew" in Fig. 6. Records of "j" differ from those of "ch" in showing small vibrations during the occlusion and the explosion. These are due to the vibrations of the larynx which are present during "j" and not during "ch." The "j" is said to be "sonant," the "ch" to be "surd."

These records and many others from the same person and from other persons (Americans) show clearly that the sounds "ch" and "j" consist of an occlusion with an explosion following it, that the explosion is more gradual than the explosion for "t" and "d," and that the explosion is of quite a different character from the rush of air during "sh." The conclusion is unavoidable that "ch" and "j" are not compound sounds, but simple occlusives with characteristic explosions.

By coating the tongue with ultramarine just before speaking, "ch" or "j" or by any of the other methods of palatography[1] a record of the contact of the tongue with the palate may be obtained. The regions of contact for "ch" and "j" are found to be larger than those for "t" and "d."

The final conclusion is that "ch" (č) and "j" (ɟ) are to be recognized as individual sounds quite distinct from the compound sounds "tsh" and "dsh."

[1] Scripture, "Elements of Experimental Phonetics," chapter XXI.

Records by a native of Potenza, Italy, are shown in Figs. 7 and 8.

The record of "Mariuccia" begins with some very faint vibrations from the "m." These are followed by stronger ones for the "a." The

FIG. 4. RECORD OF "NUTSHELL." The straight line showing the occlusion for "t" is followed by a rising line showing the rush of air for "sh." This is quite different from the curve for "ch" in Fig. 2.

FIG. 7. RECORD OF "MARIUCCIA." For "ci" there is no complete occlusion but a steady emission of air ending with an explosion. The curve differs from that of "sh" or "ch."

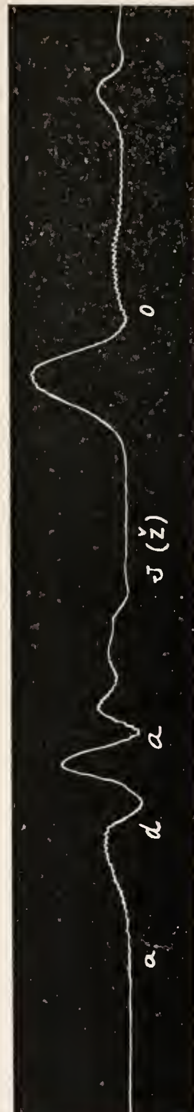

FIG. 8. RECORD OF "ADAGIO." The curve for "gi" shows an almost complete closure followed by an explosion; it is a modification of the curve for "ci" in Fig. 7.

sudden jolts in the line are the record of the two flaps of the tongue for the "r"; the small vibrations indicate that the "r" was sonant throughout (that is, that the larynx was in vibration throughout). Then follow the vibrations for "i" and the more open "u." The sud-

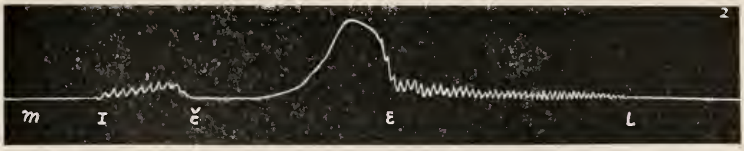

FIG. 2. RECORD OF "MITCHELL." The record for "ch" shows an occlusion with an explosion of a special form.

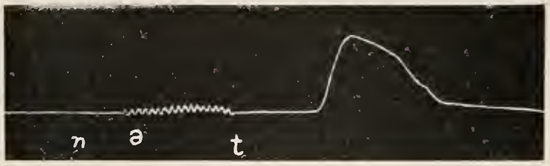

FIG. 3. RECORD OF "NUT." The explosion for the "t" is different from that for "ch" in Fig. 2.

FIG. 5. RECORD OF "ATCH" SHOWING THE FINAL "CH." The end of the occlusion and the form of the explosion are like those of "ch" in Fig. 2.

FIG. 6. RECORD OF "CHEW" SHOWING INITIAL "CH." The explosion of "ch" is the same as in Fig. 2.

den descent of the line after "u" indicates that this sound was cut short by some closure in the mouth, namely, by the tongue action for the sound "c." The line, however, does not remain at zero, but rises gradually; this indicates a steady emission of breath and not a complete closure. The partial closure is finally released and the explosion is registered in the sharp upward movement of the line. The sound "c" thus shows a sharp explosion like that of "t" but an incomplete closure. The closure is much greater than that of "sh" and the emission of air is much smaller (Fig. 4). The Italian soft "c" is therefore not an explosive occlusive like "t" or even like English "ch"; it is not a fricative like "sh"; it might be termed a fricative with an explosion. At any rate it is a distinct sound not existing in English.

The record of "adagio" begins with vibrations for "a." The first downward movement of the line corresponds to the sound "d"; this ends with a strong upward movement due to the explosion. Thereafter follow vibrations for the vowel "a." The nearly straight piece of line with faint vibrations is the first part of the soft "g"; it is almost but not quite an occlusion. It ends by the strong upward movement of the explosion. The record ends with the vowel vibrations of "o." Other records from the same speaker show even less occlusion through the soft "g." We seem justified in concluding that soft "g," which is the sonant corresponding to soft "c," is, at least in this part of Italy, not identical with the English "j."

THE RELATIVE IMPORTANCE OF MENTAL PAIN

BY SMITH BAKER, M.D.

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IT is everywhere thought beneficent and just to recognize the demands of physical pain, and to furnish prompt and effective means for its relief. Let there be but the least significant crick or colic, the dullest ache, the most transitory throb, and it is almost universally considered uncivilized not to try to give the sufferer relief from such an intrusion upon his sense of comfort and safety.

When, however, we look at the other aspect of human suffering, the one that is much more closely intimate, and yet much less evident to observers—the psychical, the mind-and-heart side of mortal suffering—we come upon the interesting if not startling discovery that there has been, and still is, comparatively speaking, by far less attention given to the truly exceptional needs of this kind of suffering than to those of physical derivation, even though so frequently these latter are of the lower order and of the lesser significance.

Of course, it should not be inferred that the significance of mental pain has never been recognized, nor that useful attempts at amelioration have never been made. Quite a proportion of the work of the sympathetic and other helping classes has ordinarily been and is now in some way to comfort and encourage and otherwise mitigate and even cure, the mental distress of their fellows. Moreover, it can be joyfully conceded that the sick-room has always and everywhere been the scene of useful effort on the part of the more strictly professional classes, through sympathy and persuasion and cheering-up and every other sort of constructive and kindly attention, to relieve the sufferer from everything which might add mental distress to his physical ailment. All this has been worthy, most useful, even though as yet it may be counted chiefly as but a sort of foundation experience upon which real systems of relief shall be built, those which shall certainly be far more truly and widely successful than hap-hazard methods have hitherto proved.

But granting all this to be true and as praiseworthy as useful, it still should not appear to be far-fetched or intrusive once more to invoke still further consideration of the relative importance of mental pain, or confidently to express the hope that in the very near future the extent and depths of this shall come to be by far more adequately recognized and appreciated; and that the art of preventing and ameliorating this shall be considered as much a matter of simple duty, as has been or will continue to be the art of preventing and relieving pain that is distinctively physical.

But first, what is "mental pain," or "*psychalgia*," as it may better be called? What evidence have we that aside from some form of physical pain there is ever any such thing as "psychalgia," that is, something which can be more familiarly and supposably more clearly noted and described than heretofore, and consequently more satisfactorily dealt with? If present how are we to differentiate it, and thus be reasonably sure that we are not dealing with mere phantoms—something that is not fixable or definable, and not to be rationally handled in any way?

Probably no one can truthfully say that there is such a thing as mental pain who has himself never suffered from it, and at times when physical pain or distress has not been present to such a degree as to obscure or complicate self-observation, beyond differentiation. For, no matter how dire the psychalgia in the latter case, the suspicion must arise that it was but merely a *quale*—quality—of the physical condition, and so not susceptible of being considered as a distinctive kind of suffering at all. To be this and to be worthy of consideration as a true psychalgia, it ought at least to be capable of being consciously remembered as an experience by itself, dissociated somewhat clearly from every physical condition save that of general well-being, and in most cases, at least, of being referred back to certain causes, which, whether true or not, are consciously regarded by the sufferer as having been of distinctively mental origin.

By way of attempt at elucidation of this requirement, let us consider instances where the psychalgia, instead of being an exclusive experience, is apparently the direct consequence of personal shock and stress, and where primarily there are various wide-spread physical changes, especially in the sphere of metabolism, all of which must be included in any truly scientific consideration of the subject. To the sufferer himself these physical changes are of little importance, except as they are explained to him as possible sources of his mental distress. To him, it is his *mind* that is distressed, not his body: for the time being, all his regard is monopolized by his psychalgia, and if not told otherwise, he may not even suspect that anything but his mind is or ever will be affected by the causal event. If he be introspective and at the same time analytic enough, he will chiefly or exclusively note that his mental horizon has become painfully restricted; that his ideation is being painfully overworked along some certain narrow lines; that his emotions are all suffused with pain, even paradoxically when little or in nowise disturbed; and that his outlook upon the future is simply too painful to be invited or prolonged. In fact, it becomes evident that all the pain which the sufferer experiences is referred to his mind as something distinct from his body, and is there, and only there, to be met, handled and helped, if possible. "Give me relief from this awful feeling of inadequacy—from the pain that accompanies every thought—from the dark that clouds all the future. Please do this, and I will be well," is the cry: and to the sufferer this is all there is that can be described or helped.

Of course, psychalgia may accompany or succeed every form of physical distress imaginable; but even here, it is characterized by the very same consciousness of intellectual inadequacy and underrating, of emotional unrest instability and depression, as well as persistent vision of future blackness, as elsewhere; and has corresponding need to be regarded and dealt with, so far as possible, as distinctive from the physical distress present.

With these leading characteristics of psychalgia in mind, suppose, by way of still further helpful elucidation, we investigate and follow the course ordinarily taken by a case of so-called "traumatic neurosis." Here there are, especially at first, clearly outlined localities in the organism whence waves of purely physical distress emanate, whose origin can not be accurately referred except to their organic source. But in time these come to be associated with certain other waves of pain, whose localization is not so apparent, either to the sufferer or to the investigator. In fact, eventually a large proportion of the suffering of the patient is seen to consist in pains which have no locality outside the selfhood that has been so direly and so deeply insulted by the injury. Often, too, because of supposed blundering on the part of his own self. or rebellion at "fate" through consideration of his present predicament in connection with previous experiences, or of vengeance against the objective cause of his present trouble, or of fear of possible untoward consequences, or of changes in intellectual strength and acuteness, emotional tone, will-power, self-control or self-direction, there comes additionally an abiding, ever-deepening sense of degradation, which eventually enshrouds him in distress that seems as coextensive as consciousness itself and as intense as imagination could possibly picture. Surely, if we have no means of absolutely differentiating the psychical from the physical pain—the *psychalgia* from the *neuralgia*—we are nevertheless not precluded from recognizing such differences at the focal points of the two kinds of distress, as to lead us rightly to deny that these may possibly require very different kinds of estimation, for the highest good of the sufferer. In fact, while splints and plasters and lotions and doses may succeed admirably in relieving the *physical* consequences of physical trauma, it should not be forgotten that the accompanying *psychical* trauma is of another order, and has very different needs, as to both estimation and remedy; and this, no matter how clear may be our notions as to the physical distress, or how this may contribute simultaneously to psychical distress, as well.

Or, take a case of developing melancholia, where again the physical and the mental seem to vie with each other in the slide downward into abject misery. Here the defective metabolism, the choked secretory and excretory functions, the muscular weakness, and all the rest, are sufficient in a way to explain the mental condition as represented by its own peculiar slowness, weakness and distress. But however much and clearly these may "explain" to the observer, they most certainly do not constitute the pain which is really suffered—the morbid self-consciousness, the overwhelming depression, the fear of self-destruction, the dissociation from the rest of humanity—in fact, the poignant psychalgia, for which only personal experience can afford correct knowledge or provide the data for anything like a correct description. To all such, psychalgia is a definite, horrid fact, not to be mistaken for any other fact in the universe.

Take again the perplexing development and especially the slow systematization of the inner experiences of the youthful hebephrenic, or paranoid. Beginning with scarcely recognized perversions of one or more sense functionings, or with weakening or perversion of the more elaborate perceptional or ideational activities, the victim duly comes to the point where everything persistently clusters about his inner self, progressively to lead on to perplexity or danger or failure, with all the poignant mental distress that naturally belongs therewith; so great distress in fact, that long before such a state of self-monopolizing is reached, there is a period during which mental pain is so predominant that often some sort of real physical pain may be welcomed as chiefly beneficent. Surely, no one can suppose that the weakness, the muddlings, the suspicions, the fears, the antipathies and antagonisms, the imperative insistences and explosions of such an one, can be confounded with any sort of physical pain whatever. Here, as before, psychalgia is felt to be a fact, distinctive, dominating and determinative.

This leads logically to the consideration of the by far largest group of psychalgias, those derived from the so-called "border-land" cases on the one hand, and from the great number of persons who in no ordinary sense are "cases" at all, on the other.

Abnormal psychology has yet an imperative need to be studied as never before, and this notwithstanding the far-reaching revelations and suggestions of more recent investigators. In this undertaking, introspective psychology, prosecuted by the right kind of self-observers, can become of such profound use, that almost everything as yet discovered may turn out to have been introductory, to say the most. Probably, there is no one who has been trained to properly look in upon himself, who does not have more or less frequent attacks of psychalgia so clearly defined, that were they accurately observed and recorded, a key would be furnished whereby not only the problem of his own morbidity could be solved, but also a standard could be established whereto similar morbid experiences of others could be profitably compared.

From cases of border-land psychalgia we often get descriptive phrases which throw light upon the intensity of the suffering, and leave no doubt as to its reality, as well. One of the most frequent of these phrases is, "Oh, I am so lonely—(or fearful, or depressed, or weak, etc.) —this unceasing, day after day, year after year, loneliness—etc." Here, as much as anything, for want of the simple instruction that as the "uniqueness" of any given individual must always carry with it a fundamental detachment from every other individuality, so must necessarily a natural loneliness reside forever in the substratum of every one's consciousness, and must normally or abnormally emerge only as endurable pathos, on the one hand, or as dire pain on the other, the sufferer necessarily goes on day by day accumulating a feeling of out-of-the-world-ness which in time gets to be so painful, that the all of life may and often does come to be subordinated to it, entirely beyond self-emancipation. Surely, it were not humane, to say nothing of its not being good sense, or scientific, simply to ignore or scout the evidence of, or to jeer at, or malign, or to continue to misunderstand the distinctive importance of such a condition of suffering as this.

Again, there is the expression, "Just show me how I can have a little bit of happiness, even for an hour, and I'll bless you as never before," and all the changes rung on this, everywhere and everywhen. For purposes of truth it must be conceded that a reasonable amount of frequently recurring happiness together with the ever-present feeling that such experiences are truly prophetic of the future, is simply a basic necessity to the perpetuity of a reasonable state of well-being; and this in spite of Carlyle's demand: "By what act of Parliament was it decreed that Thou shouldst be Happy?" The simple fact is, that all energizing, all hoping, all accomplishing which does not have an inspiring element of happiness in more or less conscious suffusion, is not satisfactory, but the reverse; and this, notwithstanding so much seems directly to the contrary. Happiness of some kind—positively ecstatic, mildly expectant, a glowing interest, realistic energizing, comforting self-consciousness, vision of growing possessions, personal ease, enlargement of the family circle, faith that sees heavenly things—happiness of some kind, is the motive force of human life; and once let the enjoyable self-tone be lowered unduly for any length of time, or its rightful possessor be too frequently or too permanently cheated or denied, and he ceases at just this point to be fully what he ought to be either by divine right or by natural law. And the consciousness of all such cessation of full-well-being—how many degrees of psychalgia are included therein! And how wide-spread too is just this same consciousness of every other form of unhappiness, with never a respite, and with no encouraging prospect.

And then, there is "disappointment"—in love, in business, in politics, in health, in preparation for life, in church affiliation, in children; disappointment in man's sense of honor, in woman's high soul, in the constancy of friends, in all ambitious prospects—for which we so glibly say, "show thyself a man," or "wait patiently on the Lord"—and think that we have said it all; and so we probably have, until we, in turn, direfully find ourselves learning very differently, through what our would-be friends call just our "own doing." Then, how different does pooh-poohed disappointment seem; how revelational, too, in that now we can see how others did actually suffer while we were regarding them as merely "weak" and consequently as but "poor things," at best. Nor does it matter really, if "one has brought it all on one's self"; indeed, all the more should we see how much does this but add to his distress, and how much does it have to do in prolonging and deepening this indefinitely; indeed, until it may most unexpectedly result in such permanent registerings, as may quite absolutely unfit him for any further useful accomplishment in life. For, first and last and all the time, it must be remembered that the outcome of psychalgia, unless acting upon exceptional constitutions, is *unfitness* for even the commonplaces of life. Of course, the exceptionally endowed individuality reacts differently, at least for a time, and for the most part, constructively; but the common cry of the victim of mental pain is, "I no longer can do as I once could; I'm not really fit for anything now"; and his subsequent life is apt only too conclusively to prove the correctness of his cry, and the predictive fear which accompanies it.

Morbid "self-consciousness," too,—how wide, vague, mysterious is this, yet how fearfully painful, especially when subject to misunderstanding, neglect, or brutality. Shall any one say that here is something that is not a source distinctively of the most interfering if not destructive kind of psychalgia? Try to get a definite appreciation of the flashy personal commotions, the wide-spread vaso-motor reactions, the stage-fright, the unaccountable antipathies and fears and obfuscations and general overwhelmings, that such a one suffers from; try to get a clear vision of all the futile efforts of intellect and feeling and will to ward off and overcome these; try to get a fellow-feeling of all that this means to the personality which would be something and do something and feel something like other people; and then see if it be possible to regard mental pain as less significant than physical pain, either distinctly, or side by side. Certainly, no one who has never suffered the pangs of morbid self-consciousness should stupidly deny their existence; for there are many, many people who go through life virtually conscious of nothing else, in any vividly continuing sense. With every glimpse of their own bodies, with every movement, with every contact with others, with every thought of planning or doing anything, with all their hopes and realizations, there is such a tormenting intrusion of painful selfhood upon consciousness, that a desperate fight for place and favor, or even for existence, is always on, and the issue seldom if ever comfortably assured. Such people, in no sense technically "insane," are yet so burdened with a veritable soul-pain, that it is only a "kind providence" which for the time being keeps them from becoming unbalanced —a providence, however, which may yet some time call very loudly to any one who happens to be at hand, to come to its help against this "mighty" scourge, and all the indecisive conflicts which are part and parcel of it.

Undertaking now a yet closer study of this widely prevailing sickness of soul, expressed in so many morbid variations of consciousness, it does not take long to come upon the truth that probably the greater proportion of these cases are primarily owing to the fact that the personality itself has never from the first been properly harmonized, that is, has never become thoroughly enough blended in the course of its development to avoid remaining other than a veritable storm-center of all the ragings of emotion and ideation and volition, which are here as incalculable as they are pain-producing. Whether this unblending is due to such disparities and tendencies in the several ancestral lines as do not admit of continuously close relationship and coordination, even in distinct individuals, or whether the course of "bringing-up" from birth onward has been such as never to overcome the natural heterogeneity of the personal elements, probably common to the genesis of every human being, does not matter.[1] The outcome, a heterogeneous or imperfectly blended or ununified personality, may almost everywhere be discovered as constituting at least a very natural soil in which rank psychalgias may easily generate and grow and forever plague and choke the possessor quite beyond description. To stand on the brink of a seething surging crater, whose sulphurous fumes never cease to stifle, and whose eruptions are always immanent and frequently realized, might afford some sort of parallel to the position occupied by some of the more deeply afflicted of these cases; only, the man by the crater might possibly recede from his danger at will; while no Prometheus was ever chained more absolutely beyond self-help to his Caucasian rock, or was more horribly subject to tormenting insults both from without and from within, than is the one who finds himself inseparable from the miseries of the species of psychalgia that are chiefly due to heterogeneity, or to this in combination with all the imperfections of our natural growth and conventional breeding.

[1] See Smith Baker, article "Heterogeneous Personality," in the *Journal of Nervous and Mental Disease* for September, 1893; also article "Causes and Prevention of Insanity" in THE POPULAR SCIENCE MONTHLY for May, 1899; also William James, in "Varieties of Religious Experience," p. 169.

Speaking of "soul-sickness," brings to mind the subject of "religion" in all its bearing upon the consciousness of well-being or ill-being, and the profound interest, comparable to the acknowledged importance of the subject, thus insured. Formerly, certain classes of people at some particular times in their lives would come more or less unexpectedly to a more or less vivid and painful view of their sinful selves; then, perhaps for a longer or shorter period, would go through a series of spasms and stresses of conviction and renunciation and pleading and aspiration; but would in time "come out" of it all so victoriously, that usually forever after God was felt to be so good and so near that "salvation" and the "joy in the Lord" thereof were more or less fully assured forevermore. Along with these fortunately "converted" people, still other classes also have quite naturally experienced such a sufficient "assurance" of their "call," that they have quite uninterruptedly found ample solace for their untoward depression and apprehension, whenever needed. Thus, heretofore, many people have actually found, that when attacks of mental pain came on, they could go unreservedly to the "fount of all mercy" and find what to themselves, at least, was satisfactory relief. Indeed, whatever criticism may be justifiable with respect to religious dogmas and institutions, it certainly is not wise to forget that the human personality everywhere has recognized and does still recognize a supreme worth in its religious consciousness, and has found and still finds its profounder weal or woe in the spirit of religion and the practical exercises inspired by this. Woe indeed is it when religious fears and apprehensions and the general gloom arising from an abiding sense of detachment and loss, comes to pervade all the soul-life and simultaneously sees no or little relief. Joy indeed, too, when relief does come, or when the general religious temperament or atmosphere or experience begets the "joy that abides," in true realization of the Source that is Infinite! It does not do for even the most clear-sighted materialist any more than it does for the most devoted metaphysician, to forget that this deepest-sounding and farthest-reaching of all vital experiences may through mental or other pain come to be but a mere travesty of the *real life,* or that such abject misery and this only may irretrievably "damn" the subject long before the pains of future perdition are possible. "Hell on earth" is not a figure of speech to very many people; it expresses exactly the sufferings of those who are the victims of the sort of psychalgia which is owing to perversions and failure in their religious life.

A concrete case of associated mental and physical distress, occasioned by a succession of experiences certainly not very common, will serve to make plain not only the comparative significance of the more intimate kind of experience, in a way that can not be mistaken, but also somewhat to elucidate the blundering and inefficiency to which sufferers of psychalgia are, let us hope unwittingly, everywhere subjected, chiefly because of failure to recognize its distinctive characteristics and needs.

The lady had reached middle life before anything other than unrealized motherhood had noticeably hindered or marred her fortunes. Then domestic troubles, loss of property, major operations came to shock and strain her in quick succession; but even these had she surmounted bravely and successfully; only, however, to develop in time the insidiously undermining of muscular control and all that goes with it, known as "Parkinson's disease." After this had reached an observable stage, it was evident that she had before her, not alone many long years of suffering from her tired painful ever-pulling muscles, for which there was no known cure, but likewise an ever-increasing danger from intercurring diseases and accidents, which could only be averted by constant care. But worse, much worse than all this, there was the horrible prospect that through it all her intellect was to remain as clear and the sensibilities as keen as ever, and that until the very last she must necessarily be the cruelly enforced observer of the entire course of most fiendish progressive physical decline. In fact, pain of body and pain of mind were to be in closest concomitance throughout. Already she had been partially apprised of the nature and cause of her disease; yet had evidently allowed herself to expect a more or less positive denial of this. But the facts were unquestionably against every view save that of unqualified affirmation—to be softened, however, as much as intelligent sympathy, general hopefulness, and patient care could make possible. Especially was it thought additionally desirable to endeavor to instruct and encourage her in the art of keeping her mind as rightly occupied on matters outside herself as possible; and also by suggesting a variety of means for combating the awful waves of depression and despair which had already begun to pass over her battered feelings and were sure to come with increased force, later on. After a month or so of this, during which time she had gradually become more fully acquainted with the true nature of the fight that was before her, as well as with a number of really useful measures for temporary relief of changing symptoms, especially those evidencing the "sick-soul" which would undoubtedly be the ground of some of the most poignant of her sufferings, she seemed vastly better prepared for her prospective ordeal, in that she had seemingly conceived and adopted the large and comforting assurance, that come what would, she would "make the best of it," and persistently remain all she possibly could be to the relatives and friends in whose circle she was to live.

Soon after this, however, she fell in with a member of a coterie of "faith curists," who assured her that she had no need to go through all that had been hinted, if not predicted, but could most certainly be "cured" simply by prayer, if only she would allow them to take her in hand. Doomed as she otherwise rightly thought herself to be, one can not very consistently blame her for avidly grasping at the promised salvation, given with such assurance, even if from no matter how really unknowing a source. Submitting both honestly and unreservedly to the efforts of the "prayer circle," she seemed to "get better from the first," and, some two months later, it was noted that she could actually carry herself with somewhat better step, with a brighter face, and most of all, with the absolutely unembarrassed confidence that "before long she would be entirely well"; for "God can do anything, as you see." One could not be entirely dishonest in feeling much of the gladness with which she was congratulated upon her improvement, or in expressing the hope that this would continue indefinitely; yet, within, one could not help anticipating none the less clearly the fateful day of abject sadness and despair which would surely come to her, when she had all too pathetically found herself disillusioned and her physical disease quite perceptibly advanced, as well. One could indeed feel glad that she had had this much respite from her mental distress; but when one thought upon what ignorance of the facts, upon what fanciful assurances, upon what perversion of the highest offices of even present-day possibilities, her temporary release from suffering had been founded, one at least wondered if the temporary "gain" would in the long run be worth the irretrievable loss of confidence, true faith, and reasonable hope that was sure to ensue. Better, it seemed, that she should have patiently continued from the first without deviation in the persistent course of mind and soul cultivation and strengthening which had been marked out, or better still which might have been marked out, had some one more capable been her adviser, than to have experienced a but specious exaltation for a season, only to fall into the direst slough of despond, suspicion, digust and what-not, as she in due season must and did. From this awful jolt in her mental life she had better have been saved, so it seems even yet. Although what a thought significantly follows; if only she could have been given the comfort without such a train of miserable consequence!

After spending several weeks or months with this sort of people, and, more consequentially, after having given them all her little savings as well, and then found them mostly "uninterested" afterwards, she returned to her home where for more than seven years she divided the slow days and tortured nights between all the horrors of the deceived, the disillusioned, the despairing, on the one hand, and the bravest endeavors imaginable to endure patiently everything, and likewise not to become too rebellious against God and humanity, on the other. And during this period what a transformation physically, was hers. Slowly, step by step, ordinary communication with every one came to be cut off; while all their sayings, doings, feelings and entire lives yet remained as patent to her as before. Then eventually came the hour when not a smile, nor a finger clasp, nor a syllable could she give, in token of her recognition of the life about her. For a couple of years or longer the only expression possible was through her clear eyes, which always seemed to be automatically trying their best to tell how truly their owner responded, really if not voluntarily, to every effort to communicate with or to help or sustain her imprisoned spirit. Once in a while an explosion of meaningless laughter, so unlike the laughter of her former self, would startle one with its unexpectedness as well as quality, but would carry little or no meaning, as only exceptionally would there be any such response to the pleasantries (which it was remembered she formerly rejoiced in) as would suggest that impression and expression had remained very closely associable. Indeed, it was obvious enough that she had now become only a bundle of impressionable tissues, organs and centers, never so keen as now, never so liable to insult, never so pitiable; simply—was now practically helpless in body—yet absolutely as active in mind as ever. Not disembodied, but body-burdened, was her soul to continue through all these months, to see on, hear on, taste on, feel on, think on, hope or fear on, rebel or acquiesce on, love or hate on—but always to be increasingly conscious of the body that was dying, dying, yet ever alive to ache, to hinder, to endanger! With Dante how truly could she have said,

> I did not die and I alive remained not.

Yet, to those who were closely about her, to the great world that but little more than heard about her, even to those who were under obligation to interpret as truthfully as possible, it may be doubted if any one ever got more than an inkling of the great mental anguish or even physical distress suffered by her, until she herself as pathetically as surely made it known. Assuredly, the manner and speech and life of the household and neighborhood did not evince much beyond commonplace understanding sympathy and effort. And as the most interested may now look back upon his own thought and care of her, how paltry, too, how inefficient, how bungling, compared with what it ought to have been or might have been, does it all now seem!

And so all had waited until, in spite of everything—in spite of the greatly augmented sensitiveness of impression, in spite of the locked-up systems of expression, in spite of slowly entombing fate, in spite of inner travail, pain and unhappiness—had waited until this most pathetic sufferer conceived and perseveringly gave to the world, what probably is absolutely unique in letters, and better than this, even, something which may possibly be so pondered by all who have to do with human suffering of any sort of the locked-in kind, that to the end of time the human heart universal shall be the better for her effort.

Imagine her then with but the slightest power of denoting her wishes, and this with uncountable bunglings and failures, sitting at her table, perhaps tied in her chair, with a series of baby alphabet-blocks before her. Her attendant opposite tries to make out what is wanted. Over and over again nothing is determined. Then it slowly dawns that she hopes to use these blocks to make known her wishes. Then, again, after weeks of trial, it is learned that she wishes to write a letter. But what a task is before her and her interpreter. Evidently, as it is not a commonplace communication that she wishes to make, the ordinary words and phrases must easily fail. But how difficult to be sure when the right letter or word or phrase is reached; even her simplest thoughts and feelings, to say nothing of the great determination in some way to succeed in more complicated expression, is so impossible. But slowly, with patience that should be crowned by all the Academies—slowly one by one, letters, words, phrases, sentences, even unto as many as eight note pages, and requiring as many as two full years or more to do it, was the precious revealing letter evolved—to be read in two minutes, to be forgotten—never! A letter so *intime,* so exceptional, so precious, that as a voice from the tomb did it come; as an appeal from the innermost soul of humanity, should it be received.

Nothing but the dire, infinite needs of the suffering soul of humanity's very self could justify the publication of such a communication; yet the justification is complete, when once we think of all the many selves that are everywhere suffering, if not from living entombments, then from death-in-life psychalgias, which if not physical are yet not the less horrible, and have similarly day by day through all time so absolutely to feel the great need of accurate recognition and efficient ministering.

Beginning our use of this letter at about its third page, she says, "While I look at the ceiling I see beyond and live in a world of thought and imagination. I take journeys, make visits, write letters—am like a live spirit in a dead body. Though I seem to be dead and irresponsive, I feel as if I were made on the principle of a toy jumping-jack, with some one pulling the string, holding my head back and mouth open. I must be a repulsive-looking object," she continues. "I must look like a fool, anyway." To one who had known her even when but partially well, and had noted her most delicately feminine appearance and ways, it is only too clear that observation of the successive steps of her progressive physical degradation was not among the least of the sources of her mental distress. "My throat and mouth are in dreadful condition. . . . My tongue refuses to work. My teeth all seem to be dying like the rest of my body. My tongue has grown short, I can hardly get it outside my mouth." No wonder that her next words are these: "I suppose books tell you these things I suffer and endure, but that little innocent word 'helpless' must be lived to know its meaning and misery. Add speechless, and the trifles of daily living become mountains of trial." And now hear the deeper revelation: "One is misjudged," she says, "misunderstood, called unreasonable, when, if I could explain, it would be the other fellow." And how full of suggestion for all: "This life of inaction and repression is full of misery. It is only with the thought of putting yourself in her place, can one get any idea of the awfulness of living in a body that refuses to do anything for you." Ah! that thought of putting yourself in her—in any one's place. What a field of enlightening, constructive imagination is here, always. "I never dreamed of such a combination of conditions and circumstances of physical suffering for one to endure," she continues. Nor was the mere fact of personal suffering all; for she so regretfully adds, "I drink my cup of poison every day, and give a portion to every one around. It is awful to live and be such a disagreeable burden. I am like a lead sinker around—[her husband's] neck. It would be easier if I felt sick and weak; but I feel all the springs of life and energy to be and do." And how the realization of soul-body anguish deepens as one reads further; "People think I am comfortable when I am quiet; but I can not be anything else. I can not move an inch, no matter how cramped I am, or how things hurt. My suffering is constant and its name is legion." Yet, in spite of all this, note how characteristically it was to be added to: "Father [her father-in-law, a fine old man who had constantly, lovingly cared for her all the days, for years] has gone home [*i. e.*, died] and left me adrift on a sea of helplessness and silence. I suffer for want of him every day. He had grown into knowing my needs as no one else could. He was hand, feet and tongue for me. It was a sore trial to him, but he was ever sweet and patient. He filled a large place in the house, and it seems very empty without him. His was unquestioning trust, child-like faith, and so free from criticism of others. He was a lesson to us all. Oh, we felt so sure to trust him." How satisfactory in every way, that so much of this letter is devoted to such an appropriate tribute to devoted efficiency and kindliness. "When you were here in May you asked me to write you a letter. I wanted to tell you there was one in the mill, but that it grinds slowly." This was probably two years or longer before surprise at receiving it came. Going back to an earlier portion of the letter, written probably about the time of the asking for it, she says: "I dread spring and summer. If every day were a zero-blizzard, conditions would be easier to bear. When all the world is alive and stirring, it is harder to hibernate. In my corner, tied hand and foot and tongue, I am like a rat in a trap—the only thing left to do is to squeal"—a pathetic bit of the native humor which when she was well had ever irradiated her whole life.

Finally, to show how clearly appreciative she was, how inwardly responsive to even such poor desultory effort as was doled out (too often when most convenient, one fears), and especially to suggest how if a system of recognition and care more intelligent, much more devoted had been employed, so much more good could have been done, let the conventional veil of sacred personality be removed from the very beginnings of the letter, and thus complete the picture as contained in its entirety: "I can only thank you," she begins, "for all your generous thoughts and deeds." Carlyle's remorse at his meager treatment of his "poor Jeanie" comes deprecatingly to mind as one now reads this again. "You are say-well and do-well bound in one frame."—What one ought to have been and done, rather. "Your Christmas book came; it was full of words of comfort. I have written to you in thought many times; it requires heroic effort to make it real. The lovely flowers spoke of you many days after you were here. It will soon be time to think of your coming again—always good to see you, and have your presence."

Unquestionably this is too personal to be published except for one reason—the immeasurable reason for calling attention anew, and with all the emphasis possible, to the need of a more universal recognition of the thickly peopled realm of psychalgia—the mentally anguished, the sick-of-soul—as well as to the never-lessening need there is of finding ways and means for more successful amelioration of such suffering, and of applying these with an efficiency heretofore unattempted. How often has one in the presence of this unique sufferer, as has been the case in the presence of many another less distinctive, felt an utter unpreparedness for rendering the relief which instinctively one has felt to be needed. Yet note how she understood, magnified and appreciated what little one did attempt. Could one have been intelligent enough, skillful enough, sympathetic enough, and could those in more immediate association with her have been similarly endowed and prepared, what indeed might not have been done to relieve, if not the bodily suffering then the mind and heart suffering, which was ever so present and so insulting.

LANGUAGE STUDY AND LANGUAGE PSYCHOLOGY

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In The Popular Science Monthly for June, 1907, Professor Alexander Hill, the master of Downing College, Cambridge, contributed an entertaining article on "The Acquisition of Language and its Relation to Thought." What he had to say about the proved value of the study of Greek and Latin sounds like a brief for the classics, and ought to be more valuable as testimony than the arguments of any professed classicist. It is thus that Presbyterians who value tradition are fond of quoting Dean Stanley's admission of the priority of their system of church government. So I am fond of quoting one of my candid colleagues of the anti-classical battalions, who admits that much first-year laboratory work in science is as valuable, educationally speaking, as dish-washing. But, after all, the conclusions of Mr. Hill's essay lead away from the classics, at least as a medium of general education; and his generous admissions of their tried worth as instruments of training might, though unfairly, I think, be construed as the sort of admission a skillful debater, flushed with anticipated victory, will make of the strong points of his opponent's case; not to provoke a verdict for his adversary, but to gain credit for fairness on his own part.

A magazine article has some of the limitations of a sermon, due to the special advantage that it either never gets answered, or the answer must be addressed to different readers: even if it reaches the same public, no real debate results after long lapses of time. But an essay so stimulative and provocative as Professor Hill's calls for comment, and in the main rather for approval than for contradiction. There is instruction in it, too, for classicists, which a classicist may do well to urge on his fellows. There are observations to challenge, because they seem mistaken, and it may be well to point out that Mr. Hill's conclusion is a recommendation of change, to see what the result of change may be: it is not a consequence drawn from the observations of fact that went before it.

In the comment I am about to make, where considerations of space do not admit of full quotation, I shall do my best fairly to state the purport of Professor Hill's remarks, if for no other reason, for the sense of personal obligation I feel toward him for his pleasing and instructive "Introduction to Science" in the series of Temple Primers. But I make free, by virtue, perhaps, of the classicist's *hysteron proteron,* to rearrange the order of the original argument, even by transposing sentences from their own paragraphs, the which aim at no formal logical development.

I. *On the Part of Language in Education.*

Language ought to occupy a predominant position in school life.

II. *The Classics in Language Training.*

The mind-making property of the classics has been established beyond all doubt by innumerable experiments made upon juvenile minds of all types. It does not appear to me that, in the face of this mass of accumulated evidence, it can be regarded as a question open to dispute.

III. *The Classics vs. the Modern System.*

The essential difference between the classical and the modern system is the difference between training and teaching. A classical education is practically a training pure and simple: a modern education is a combination of training and teaching with mainly a teaching aim. . . . Like most other questions, there is no absolute distinction between the two systems—their difference is a matter of degree.

IV. *The Classics still Promise the best Training for the Professions.*

V. *The Classics not suited to Commercial Training.*

On this point I would make the obvious comment that the preparation for commerce, business and the trades, formerly entrusted to the apprentice system, has now been systematized through the "business college" and is being taken up in the *omnium gatherum* of the state university. So the "engineer" now gets his practical experience in the form of laboratory work at a technical school—but must often go over it again in the shops when he leaves the school. However much the classics might clarify the judgment and purge the taste of such students, it may well be that the classics have no closer claim upon them than when they were trained under the apprentice system. But sincere reflection would, I feel sure, persuade the most radical that classical study includes what is, for young people, the best training element in scientific study, viz., the accurate observation of phenomena, and the analysis and synthesis of the language crystal is a sort of crystallography of thought, with a subject matter intensely human. Students of my own who have gone over to the practical side have had no sort of doubt, that they carried with them minds trained for the apprehension and combination of phenomena.

VI. *Substitutes for the Classics.*

After all his generous recognition of the tried educative value of the classics Professor Hill concludes:

I have but one explanation. It was the rebound on to English which the classical drill produced. We were ceaselessly searching the pages of the dictionary. We were learning new words. We were studying English syntax.

These be fine words. We must admire them for their style, and we may fancy that this style is due to the classical study to which Professor Hill pleads guilty in his youth. Far from minimizing the force in these words we may as well admit that they contain truth, but is it the whole truth? Many persons have learned to write English without having studied any foreign language and without having studied English, even, in any way worthy the name. But school systems are not devised for such as these. Speaking generally, the English stylists have caught their trick from their classical studies, as Calverley's matchless versification has been attributed to his rigid training in classical verse-making. On the other hand, the lucidity of French prose, the stylistic excellence of which none but the French ever seem disposed to question, is supposed to be due to the direct study of their native tongue. A writer in *The Athenæum*,[1] put it this way:

> As our best English writers have learned how to write clear and accurate English from their long training in the subtleties of Greek and Latin grammar, so the French have attained their skill through the scientific teaching of their native tongue.

Certainly there can be small question that Quintilian's system of teaching, which laid stress on the mother tongue, failed not to teach the art of clear writing. But, given a method so thorough and detailed, one can not imagine his pupils to have saved any time as compared with Cicero, who attributed his attainment of style to his translations from and into Greek. Still, the Greeks, like the French, learned to write by studying their own language—which proves nothing against the value of discipline in a foreign language, for they also got their education without any substantial drill in mathematics.

Yet, after conceding much of what is claimed for the possible sufficiency of a modern language or the native tongue to meet the boy's need of language drill, it remains an open question whether, in giving up the classics, the loss in thoroughness and in interest might not exceed the supposed gain in time. There are two points we must not overlook, the value of the finger in the dictionary—twice emphasized by Professor Hill—and the great syntactical variety of the classics. These values, and particularly the first, can hardly be overestimated. In seeking to realize their peculiar part in classical study, we can do no better than begin with Professor Hill's own happy figure in which the Greek chorus is represented as a puzzle which the student has to rearrange into English. This accords with a favorite illustration of my own, which I point with Lewis Carroll's familiar line:

> He set them conundrums to guess.

In the puzzle lies a strong element of human interest. In my boyhood I used to notice how some puzzle of fox and goose and corn would set half a village to work to get them carried by twos across a stream—so stringless is puzzleland—without one animal or the other being left free to devour its natural food. A simple arithmetical catch would exercise the idlers at a cross-roads store for hours. Let us insist upon the human interest and the educational value of the puzzle and the riddle, and if my simple illustrations drawn from modern experience do not suffice to carry conviction, a pretty paper on "Riddles" in

[1] October 13, 1900, p. 473.

Mr. S. Baring-Gould's "Strange Survivals" will furnish better ones. Nor can we put his essay by without having been brought to think of how Carlyle was fain to ring the changes on the *cunning* of the *king*.

In the study of Greek and Latin we are confronted with language puzzles of the very best. Their solutions are in the reaching difficult, but when reached inevitable and convincing; and I do not hesitate to say that the means for reaching them are the best adapted to the end of any means now in existence. This means much. The natural boy likes a puzzle. He is rarely unwilling to work it out to a convincing solution. He does not shirk difficulties, but he wants to be sure of his conclusion. With a limited supply of books at his command, he can be more sure of his conclusions for the classics than for any other language puzzle whatever. To take the case of Latin, it is probable, in view of the narrow range of school authors, that a boy's Latin grammar more nearly accounts for his every possible difficulty, whether of form or construction, than does the grammar of any modern language. Such complete codification of usage as he commands in his Latin lexicon can never be anticipated, so far as I can see, for any modern language. Certainly no dictionary of equal convenience in the using can compare as an instrument of precision with the lexicon of Lewis and Short. Let me confess that the first fact that gave me the temper of the student was the discovery that I could find in Andrews's "Latin Dictionary," the inferior predecessor of the one mentioned, nearly every puzzling passage explained; and for some reason the condensed explanation of the lexicon by citation of parallel passages convinced and interested me more than any possible translation by an indulgent annotater. I suppose, to use one of Professor Hill's own figures, I more enjoyed my own piecing-up of the mosaic. A note seemed "telling" and I did not like to be told.

I keep within the bounds of truth and soberness, I think, speaking not as an enthusiast for the classics, when I assert that the modern-language puzzle can never be as difficult as the Greek, and more particularly the Latin puzzle. The reason for this, granting its truth, is not altogether apparent to me. The secret of the difficulty does not lie, I am persuaded, in the synthetic character of Latin. It does not rest primarily in the greater difficulty of Latin forms and syntax. Greek was always easier for me than Latin, and this experience is general, though not universal. I admit the greater difficulty of Greek forms. I agree that its vocabulary is more extensive, while English does not so easily help us to arrive at it. I believe the Greek syntax to be the more complex, and to involve rather more than fewer rules and principles. Yet with considerably more preparation in Latin, Demosthenes in the "De Corona" was easier to me than Cicero in the "Second Philippic." Easy and hard are relative terms, I know, but it might be possible to secure and tabulate a large number of opinions of students as to their sense of the relative difficulty of languages. My personal experiences have been entirely convincing to me. While still a college student, but with five or six years of Latin behind me, I began one summer to study German privately, and after a careful reading, not conning, of the grammar, I set out to read a German novel. In a few weeks I could get on with it with some ease, and much more rapidly than I could then read Latin. In the next year's work at college Lessing's "Minna" and Schiller's "Tell," in long assignments, caused me much less labor than Latin authors did. Even now, after two decades of Latin teaching, with forms, syntax and vocabulary under good control, the Latin language puzzle at times presents difficulties. True, I require of myself greater accuracy with the Latin, but after a few weeks desultory dabbling with Spanish, I can read with enjoyment and a fair understanding a play of Echegaray or a novel of Galdós with far less concentration of attention than it requires to read a fresh bit of Ovid, or to reread for class preparation any but the most familiar satires of Horace.

My own experience aside, Professor Hill's surmise that the classics might be advantageously replaced in the educational scheme by a modern language or English seems to me not to weigh against the actual experience of a master in an English public school, Mr. John Charles Tarver, who thus expresses himself in his "Observations of a Foster Parent";

> The claims of history and geography are on the surface so obvious that I am tempted to a little piece of autobiography. Be it known, then, that my first ambition in teaching was to teach history. I had as little faith in Greek or Latin as the most ignorant of self-made men. I believed that great weight should be given to English literature and English composition; and as for language teaching, I saw no necessity for anything but French and German. Therefore when I speak of Latin as the best educational instrument, I speak with the authority of a person who has tried others. My opinion would be of no value at all had I never stirred out of the classical routine. Similarly, if I do not share the popular views about history and geography, it is after, not before experience (pp. 174–175). . . . The one great merit of Latin as a teaching instrument is its stupendous difficulty. Greek, in spite of its wealthy vocabulary and infinitely numerous inflections, is child's play to Latin (p. 79).

But why is Latin so much more difficult than a modern language? I find it hard to advance a reason. The differentiating factor lies not, I am convinced, in the forms. The German noun—unless its article were so helpful—is certainly as difficult in its forms as the Latin, and the Spanish verb seems to me even more difficult; but I make a fair headway in finding out the sense of Spanish or German, in spite of a very poor knowledge of the forms. This can not be done in Latin. Perhaps one reason lies implicit in the modernness of the modern languages. Their sphere of thought is modern and therefore mine. At least, I once heard this explanation advanced, with somewhat explicit reference to the ethical value of classical studies, by a great scholar and a wise man, the Reverend Dr. John A. Broaddus, of Louisville. The only other reason I can divine lies in the greater variety of word order in Latin, the capacity of the phrase for variation, its unfixedness, as compared with the modern phrase. This is the only reason I can give myself for the close attention I must pay to get Horace's meaning in the "Satires," where language and syntax are thoroughly in possession, and the thought is plain and even *bourgeois*.

In the debate as to the respective educative value of the classics and the modern languages, the facts seem to justify the statement that the solution of the classic language puzzle requires greater effort, attention more concentrated and for a longer time. If this be true, and we abandon the old for the new, we must anticipate some necessary loss. It remains for the advocates of the change to demonstrate the contrary. In my opinion, the rebound from Spanish or German does not promise so active a motion. Possibly a language of a type very different from our own might produce a greater rebound. The Japanese who is learning English may well feel it a severer training than a German would. For myself, I can but think that the study which requires the greater concentration, like Latin, is more educative than the easier study like Spanish or French. I can but believe that the puzzle of a game like whist furnishes a higher recreation than the lesser puzzles of a game like euchre.

But Professor Hill thinks it likely that the due linguistic training of an Englishman might be had from the study of English, and above all of Shakespeare.[2] Supposing this to be true, who shall tell us that English would require, in the end, less time? Or that the study of English might not prove humanly less interesting? It is by no means clear that the paraphrase can replace the translation. Cicero, who tried the paraphrase of Latin as well as translation from the Greek, forsook the former as involving, if his stylistic model were well chosen, an almost sure replacement, in the paraphrase, of the better by the worse. In my mother's generation children were taught to parse and paraphrase Milton. I have heard them as adults describe the awful tediousness of it, in the tone of those who attribute their disregard for formal religion to a training in "The Shorter Catechism" and the strictness of the

[2] This point is well answered by the following citation from Dr. Arnold (Stanley's "Life," II., letter cxxxviii): "My delight in going over Homer and Virgil with the boys makes me think what a treat it must be to teach Shakespeare to a good class of young Greeks in regenerate Athens; to dwell upon him line by line and word by word, in the way that nothing but a translation lesson ever will enable one to do; and so to get all his pictures and thoughts leisurely into one's mind. . . . And how could this ever be done without having the process of construing, as the grosser medium through which alone all the beauty can be transmitted, because else we travel too fast, and more than half of it escapes us? Shakespeare, with English boys, would be but a poor substitute for Homer. . . ."

Scotch Sabbath. And what becomes of solving the language puzzle if we study English? Puzzles enough and to spare in Shakespeare, yes. But the puzzles appear in spots as compared with the somewhat continuous bepuzzlement of the classics, and their solution involves, in the main, only some bit of glossarial definition; it does not often demand a complete rearrangement of the thought.

Herein lies a cardinal distinction. As we read or study our own tongue we enjoy immediately something like a three-quarter apprehension of it, because it is English and because it is ours; and being what we are it is irksome to apply ourselves to getting a full comprehension. The truly educative thing in language study is, I take it, the effort to convert loose apprehension into thorough comprehension, and the greater the immediate apprehension, the less the effort and the less the stimulus to pass on to full comprehension. This point has been well made by Dr. Arnold:

> It has been my wish to avoid giving any pupils any Greek to do on a Sunday. . . . But I find it almost impossible to make them read a mere English book with sufficient attention to be able to answer questions out of it; or if they do cram themselves for the time, they are sure to forget it directly after.[3]

Plato-Socrates made this point long before in the Meno by asking whether one would earnestly seek and endeavor to learn what he thought he knew already, not knowing it—until at last, having fallen into embarrassment by being shown his ignorance, he longs to be taught.

In hearing or reading our own language we largely anticipate what is coming and this is what renders us liable to be bored. Thus the very ease of our apprehension makes us inattentive. With persons who speak like a book and with parsons at sermon, it is often enough to hear the beginning of a paragraph and wake up again at its end, quite sure we have absorbed the contents of a long stretch of discourse. Psychologically speaking, we stand in a very different relation to our own and to a foreign language. What we speak or write our motor currents, starting in the brain, we will say, transmit to our vocal organs or our pens, along nerve-fibers so habituated to such impressions that the consciousness does not become alive till we hear what we have said, or read what we have written. This is proved by the not uncommon experience that, while writing unconsciously, we spell correctly words that we misspell if we consciously attempt them: which shows how trite the native word and phrase become. On the other hand, when we read or listen, our sensory currents, transmitting to the brain what we see or hear, throb the more actively in proportion to the novelty, the strangeness of the object of consciousness. The only real stimulus is the novel stimulus. Our native speech, whether in motor or sensory transmission, provides less stimulus of novelty. It less quickens the attention. It becomes automatic. In our own language we read along cheerfully,

[3] Stanley's "Life of Dr. Arnold," letter No. 8, v. 1, p. 74.

with a very benumbed consciousness, not realizing how little we are understanding. A foreign language rouses our attention, and all the more in proportion to its strangeness. The modern tongues are modern and in part already ours; Greek and Latin, by their strangeness, more pervadingly quicken the attention.

And what becomes of the finger in the dictionary—a very different thing from a glance into a glossarial index—if our language study be English? Conceding that the same diligent attention might gain as good results from the English dictionary, how are we to drive students to give it such use? Driven they must be, for they think they know already. The strangeness of Greek and Latin furnishes the spur, does the driving for us.

VII. *Teaching Literature.*

> Boys, whatever their career, must have some literary training, say the apologists for the present system of teaching classics. This is my contention also, but I advance it with still greater emphasis. The literary training obtained whilst learning Latin and Greek is indirect, accidental. It is too serious a part of education to be thus left to chance.

What a problem Professor Hill broaches here, literary training! President Woodrow Wilson, on the other hand, thinks that literature may be learned, but that it can not be taught: it certainly seems as if, in Teutonic lands, there is no developed method for teaching literature successfully. Nearly a score of years ago a despairing reviewer in *The Athenæum* wrote the striking phrase that courses in literature inevitably dwindled into "chatter about Shelly and the Harriet problem." One who like Professor Hill has admitted that "A man who has had a classical education has a craftsman's feeling for literature: he regards it as an artist regards a picture," has answered in advance his objection that "The literary training obtained whilst learning Latin and Greek is indirect, accidental." Granted, but what a splendid by-product—and I believe it to be only a by-product—"a craftsman's feeling for literature."

VIII. *On Practical Studies.*

There is the utmost haziness in the popular mind as to what studies are "practical." Nine out of ten would put mathematics at the head of the list. Only the simplest arithmetical processes are in general use, however. Only an infinitesimal proportion of those who have studied algebra, plane and analytic geometry, or calculus have ever made use of them. Adding machines and computation tables keep the bulk of the world's commerce straight. But nobody has studied Latin without being or feeling himself surer of his control of a third of the words of his daily speech. I have never thought the etymological a particularly strong argument for studying Latin, but it has been given me by students of my own whom I didn't think I had succeeded in getting to learn Latin. That the close study of an English dictionary might do much the same thing for the boy, I freely admit; but the mass of mankind when they read are casual readers, and the casual reader does not use a dictionary.

IX. *How the Classics should be taught.*

Professor Hill's views on the teaching of the classics, and his strictures on certain proposed innovations, seem to me eminently sound. He has probably not heard of sundry American proposals to "enrich" the study of the classics, though the greatest enrichment would be to restore prose composition to its old place of importance. The indispensable value of the classics is the concentrated effort required in construing and writing them, the piecing-out of the English-classic language puzzle: this, and the finger in the dictionary, constitute the values that a modern language or the native speech will never—I do not say, can never, save in so far as what will not be can not be—replace. Whatever "enrichment" impairs these values is like a drug that would sap the heart while making the hair grow. It is abundantly right to say, with Professor Hill:

> For schoolboys Greek and Latin are exercises in grammatical expression, and nothing more. . . . Neither legend, history, philosophy, nor art has influenced the vast majority of the boys who have thriven on a grammar-school training. Stultify the grammar, distract attention from accidence, syntax, prosody, and the value of the gymnastic is reduced to nil.

X. *On the Relation of Language to Thought.*

> If we but knew the most rudimentary principles of the psychology of speech! What form of language is best suited for the expression of thought? What form of language is most favorable to thinking? . . . The test of the elevation of a language, from the evolutionary point of view, is its simplicity, freedom from ambiguity, correspondence in the order in which words are used with the sequence in which ideas successively occupy the focus of consciousness. "*Amabo,* love, future, I," is as swift an expression of thought as "I shall love"; although it does not place the constituents of the idea in the order in which they pass across the mirror of my mind; my personality, in the case of such a general proposition, takes the lead. "*Lucretiam amabo,*" no doubt, gives the order aright. But neither conglomerate allows of the inversion "shall I love?" Picking up the schoolbook nearest to hand, I have essayed the "sors Virgiliana." This is the sentence which my finger touched: "Relinquit animus Sextium gravibus acceptis vulneribus."[4] It seems to me incredible that this sentence expresses the thought as it formed itself in Cæsar's mind: "Leaves it the soul Sextius by or to grave by or to received by or to wounds." Surely the idea of the personality of Sextius preceded the idea of some one fainting? What purpose is served by three times explaining that it was by or to (leaving it at the end an open question which) wounds?—"ibus," if it does not impress the mind of the reader as the really important constituent of the phrase, is unduly heavy for a mere inflexion. Cæsar did his best with the language which his unlettered ancestors had bequeathed to him: but he was to be pitied in that his thoughts when they went abroad must walk in irons.

We know little indeed of the psychology of language—which leaves us perhaps in little worse case than when we stand before the psychol-

[4] "De Bello Gallico," vi.

ogy of anything else. But our analysis of the main language problems must at last rest, I think, on the following observation: Language, the joint creation of the organs of speech and the hearing ear, became, by the invention of writing, a thing of written tracings addressed to the eye. Mere speech is not, in the nature of things, an object of study. The child learns it by ear, but his ear no more studies it than the eye studies optics to improve the sight. What we really want to know, and what we study in school, is written language, and we must always bear in mind the artificiality inherent in the strange medium. It can matter nothing to the infant who hears it whether he hear Greek or Zulu or English. He learns what he hears as unconsciously as a dog wags his tail. The conditions under which one tries to learn how to speak a foreign tongue are usually quite abnormal. That involves some conscious effort, doubtless, but whether the learner be a prince or the boots in a hotel, his most effective means of learning will be by ear, he must let himself be taught to hear. The rest is easy, provided he is young and has not been made self-conscious by a half-knowledge of grammar. Learning to speak a foreign language is, however, not a school problem, and I can foresee no conditions in the near future under which it is likely to become one. It would be well if those who prate of the practical value of the modern language would candidly add that for use as speech the French, German or Spanish that they recommend are, under the conditions that obtain, practically—if not potentially—as dead as Greek or Latin. It would be instructive, too, to get a statement from a thousand random men, who studied a modern language at school ten years ago, as to how many times it has been necessary, or would even have been convenient, to speak the language. Not but I would have persons learn to read or, if they could, to speak several modern languages, but if the Latin grounding has been thorough the acquisition of a reading knowledge of a modern language—and this is for people in general the practical thing—is a mere bagatelle. Again let me repeat it, for school purposes language study means the study of written languages, which is artificial and secondary. But though written language has developed habits and turns of its own; and writing has given to the registered phrase stability, variety, intricacy, whence the written word has acquired a special psychology of its own: yet it has never lost its inherited traits as speech.

This observation brings us to consider the order of words in language, a point on which Professor Hill betrays, *sit venia verbo,* some aplomb. He likes not an arrangement of thought in a different sequence from his own. Taking "*amabo*" for his instance, he rethinks it as "love, future, I," with some cavil at the relegation of his personality to the rear. In "*Lucretiam amabo*" the beloved, as he hints himself, might happen to prefer the Latin emphasis: if there were any emphasis. The truth is *amabo* is a crystal, a synthesis, and it appeals to the mind as a whole. It is as much an entity as an icicle, the perception of which need not involve the thought of water, much less of hydrogen and oxygen. *Qua* analyst, I may divide *amabo* in one way for its syllables, and in another way for its root and stem, its tense and person signs. *Qua* hearer or reader, the unit is *amabo,* which I think I can mentally realize in rather less time than I realize "I shall love." My eye may see *ama-* sooner than it does *-bo,* but my consciousness appropriates them simultaneously. It is more probable that my eye sees *amabo* all at once, just as it is immediately aware of a flag, which it may then analyze as a tricolor, and last as three colored stripes. It requires no special act of enumeration to be conscious that a group is composed of five or six individuals, but the group is probably first to rouse my attention and my perception of it is a synthetic perception.

It was only the little lad learning to read from a hornbook at his grannam's knee that ever passed through Spencer's struggles with "the black horse," for it is an utter fallacy that "black horse" and "cheval noir" are, in speech, ever broken up into "black" [here ponder on "black"] and "horse"; "cheval" and "noir." And we shall not be entirely brutal if we disregard the distress of an American critic of style who thinks of "bay-horse" when he hears "cheval" and is pained to have his impression corrected by "noir": What an agony "the [bay] horse is black" must cause him. Nor need we make a prolix appeal to grammar or psychology to prove that "black horse" is, in the evolution of speech, shorthand for "the horse is black." This probably did not trouble our savage forefathers any more than it troubled the Romans, to whom either *niger equus* or *equus niger* alike meant "black horse" and "the horse is black."

Equally unhappy is Professor Hill's analysis of the Cæsar sentence cut at random after the manner of the *sortes Virgilianæ.* In its own context the sentence stands in the middle of a paragraph, and the reader coming upon it knows that Sextius has jumped from a sick-bed to rush with a few followers upon the attacking foe: paulisper una proelium sustinent . . . relinquit animus Sextium . . . gravibus acceptis vulneribus. To me also it seems incredible that the thought that formed itself in Cæsar's mind was anything like "Leaves it the soul Sextius by or to grave by or to received by or to wounds." The thought of Cæsar was in three phrases, "for-a-little together the struggle they endure . . . swoons Sextius . . . from dangerous received wounds." It can not be said too often that for the understanding the phrase is the unit. Ay, whether the medium of interpretation be the ear or the eye, the hearer or reader is simultaneously conscious of the whole phrase. When I say hearer or reader I mean, of course, Cæsar's predetermined hearer or reader, not the tiny learner spelling out *r-e-l,* etc., nor the older dullard who calls out words like sums standing in a column to be added. There is a trick of rhetoric, to be sure, in Cæsar's chiastic order, meant to bring the verbs together in contrast, but it is easy to overstate the better adaptation of one word order than another for the understanding. The plain church-going American seems to find no difficulty with the line "Hangs my helpless soul on Thee" which, for rhythmic reasons, I always want to sing in the form "Helpless hangs my soul on Thee"; and "departed this life" is a formula very like *relinquit animus Sextium*. The desire to put the verb or other predicate forward has given rise to English turns like "There comes a stranger" or, in German, with wider reach, "Es klingelt die Glocke," "Es sperren die Riesen den einsamen Weg." Our American newspaper headlines are particularly given to this sort of striving for emphasis. I have seen examples of it occasionally in such carefully edited papers as *The Evening Post* or *The Courier Journal*. It runs riot in the text as well as the headlines of our local daily. Precious instances I recall are "Singing were"—A, B, C,—"Tyro is he"—who didn't enjoy so and so. And even in the high literary realm our now "Englished" minds still retain a great flexibility for word order, as for instance in parenthetic interruptions of the stream of thought, such as we find in the following: "No one else can feel the same interest in them [the boys], and no one else (I am not speaking of myself personally, but merely by virtue of my situation) can speak to them with so much influence."[5]

Shall Professor Hill assess Cæsar's feeling for the natural order of thought? Then he must take Echegaray, and many a Spanish author besides, to task, and ask them to make their stream of thought flow Englishly. He must ask the Germans to think more naturally. I can not think Cæsar was less natural than an Englishman and the natural order for Cæsar's thought was the order bequeathed to him by his untutored savage ancestors who spoke Latin; for the order of words in any given language is, I suppose, conformed to the order of thought—but hardly to the extent American Latinists were asserting a decade or more ago; as though every Latin sentence were arranged for emphasis in a diminuendo, beginning with a scream and ending in a whisper.

Professor Hill's rethinking of *gravibus acceptis vulneribus*—"by or to grave, by or to received, by or to wounds"—is scarcely less than grotesque, though I believe there is a recommendation abroad in the land to use as one reads Latin some sliding slotted card which shall reveal to the reader *gravibus* alone, leaving him to ponder the "from," "to," "by," relations before he passes on to *acceptis*, where, another wait, and so on to *vulneribus*. The propriety of this method may be tested by reading, with long, reflective pauses, as indicated, the following English sentence: "The chief made his son . . . a present . . . to the king." Here, stopping short, with false phrasing, ruins the sense. The truth is, the sentence is not "connected up" by consciousness till the last word, king, is reached. The mind, if not the ear, hears the whole

[5] Stanley's "Life of Dr. Arnold," v. 1, p. 152.

phrase at once, as the mind, not the eye, sees a complete circle of fire when the burning tip of a reed is turned rapidly about. False phrasing is like the false word division that misled Mr. Pickwick, the antiquarian, when confronted with the inscription

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It may seem *de trop* for an Englishman to indicate gender and number in his adjectives, but all the Romance peoples do it, and a German further indicates case. My experience as a teacher has shown me that the Latin ablative absolute, when you allow a slovenly translation, is a thing the dullest student fails not to recognize. Given the full phrase, and it is a blunder to give a student less, there is little more likelihood that even a dullard would, in our Cæsar sentence, for one moment think of the dative than the average reader would be likely to think of "bier" if he heard the sentence "Malt was used in making this beer." The fact is that what is theoretically equivocal in language is rarely so in experience. So true is this that only a few years ago French scholars went to the extreme of denying *in toto* the possibility of conscious effort to avoid verbal confusion: as though the whole stylistic juggle with synonyms—a phenomenon, to be sure, scarcely to be reckoned with in unlettered speech—did not look the other way.

On this point, I can contribute an interesting observation of a child's feeling for homonyms. My small niece, still under two, called her father, among other things, something like "baba," and we could not distinguish this name from her pronunciation of "barber," a word she probably had never heard till her little brother Jack went down the street one day to get his hair cut. Several of us, wishing to test whether she also confounded the two individuals, asked her questions like "Did baba cut brother Jack's hair?" But we never tripped her. The answer was always prompt as rhyme, "No, no, the baba." Were the two "baba's" she pronounced the same to her ear or did her acoustic image of the word "barber" contain the two very slightly trilled *r's* of our southern accent—though to the best of our observation they formed no part of her vocal reproduction of the image? Or was the differentiating factor in her mind the article "the"? The same child was not troubled by shifts in word order. One name she used for her father was "daddy-pops," and in trying to confuse her over the two "babas" I reversed it to "poppy-dads," which she instantly appropriated without a hint of confusion. A very simple shift of order will confuse an adult—perhaps the adult is more easily confused in this way—as I feel confused when I read from the Marseillaise hymn—

Contre nous de la tyrannie l'êtendard sanglaut est levé—

though it is so easy to rethink it as "Against us tyranny's standard of blood is raised."

No, the phrase is the unit. Of this I once had an almost convincing demonstration. A class was beginning Cicero's essay on old age and, as there were no books at hand, I began to read the first chapter aloud, slowly, and by phrases, with the result that I secured in this oral way a much better translation than the class brought up next day for their prepared lesson. If any one wants to convince himself of the superiority of Virgil in the narrative style to any other Latin poet, I know of no better test than reading him aloud by phrases: his brief phrases—not his words—move with a simplicity and naturalness not unlike the prose style of King James's version.

XI. *Analytic versus Synthetic Languages.*

We can not resist the impression that modern Greek and Italian, as they are but the ruins and vestiges of the languages in which Demosthenes and Cicero spoke, afford by comparison but miserable accommodation for thought. From our extremely small experience of the speech of the world we judge that, in the case of the few languages which we know, evolution has proceeded backwards: the better organized, and therefore, from the evolutionary standpoint, the higher language has given place to the lower. . . . Greek and Latin were not made by cultured Greeks and Romans. The language took form in the converse of their illiterate ancestors. Literature, upon which the beginnings of culture rest, closes language building in the larger sense. Zulu is a more highly flexional language than Greek. . . . The language of the Zulus is not great because it is complex in form. Every language becomes great when greatly used—Greek from Demosthenes's mouth; English from Milton's pen. . . . The only evolutionary tendency in language which we can recognize is this tendency towards analysis, toward dismemberment. So great an authority as Sir Charles Eliot, vice-chancellor of Sheffield University, who perhaps knows a greater variety of languages than any other man, from Portuguese to Russian, from Turkish to Japanese, languages of central Africa and of the Polynesian Islands, tells me that he considers that this progress favors thought. Gender, number, case hamper language, restrict its flexibility, impede thought. A monosyllabic root-language, such as Chinese or Burmese, is a swifter and more precise solvent of thought than are the highly inflected Bantu tongues. If this be true—and it does not seem to me open to doubt—it is easier to think in English than in Latin.

I have not the least doubt that it is easier for Sir Charles Eliot, Professor Hill or me to think in English than in Latin. The great educative value I assign to the study of Latin lies precisely therein. The rethinking of Latin into English can not fail to be tremendously more difficult than the rethinking of any modern cultural tongue into English. But Professor Hill is dealing with postulates, not demonstrations. Who shall show us that Cicero's Verrines cost more effort in the thinking and phrasing or appealed less simply and directly to his audience than Burke's "Impeachment of Warren Hastings"?

The scientist is very apt to carry a chip on his shoulder when the word evolution is mentioned. He seems to feel it treason to science if evolution is not regarded as a universal principle, as absolute in its operation as the law of gravitation. Because he believes in progressive development and the survival of the fittest, he mechanically postulates that whatever is is better than all that has passed away. Applied to the institutions of men this principle is abundantly untrue. If it comforts one to classify the differentiation of organ and function from diatom up to man, and the general simplification of structure observable in the historical development of languages as they grow older, under the one label, evolution, he is welcome to do so, but he must meet the difficulties and see the differences. If it is a simplification that the Romance languages have replaced Latin synthetic cases by prepositional phrases, why, after having acquired an analytical future, did they convert it into a synthetic: why has Spanish developed *hablaréis* "you will speak" from *hablar habéis* "you have to speak"? Who will assure us that the Latin case-endings did not similarly arise from some sort of attachments of prepositions to their nouns? Why is -(*i*)*bus* too heavy for a mere termination? [What is there about -*bus* that catches the ear of persons who hear Latin? Shakespeare's Costard hits off some of the catching elements of spoken Latin in his honorificabilitudinitatibus, and I can testify to the prominence of -bus in the gibing attempts at Latin word-formation I have heard from mockers.] Who can seriously maintain that -"*bus*" attached to a Latin stem is inherently any more ambiguous than "by" or "with" prefixed to an English noun? What -*bus* was to start with, philologists surmise, they do not know. But they do know that Spanish *migo* is Lat. *mecum* synthetized and reanalyzed again in *con migo* which is *cum mecum*. The psychology of the doubling they understand, but they don't drop the -*go* from *migo;* and they accept the fact for the fact, content with the unlettered ancestry of Spanish or Latin or English. Who then, I repeat, shall assure us that the Latin case endings did not originate similarly from some prepositional affix? It is absolutely certain that Latin *amabat* "he was loving" has been synthetized from an independent word meaning, either "loving" (ptc.) or "for-loving" (infin.) plus -*bat* "was."

The truth is that all along the line language submits itself to synthesis. We have an interesting exhibition of this in the colloquial American "kinder" and "sorter," for which our language has, I conceive, a real need as a verb modifier. At least I can not express in formal language the very pretty group of associations suggested to my mind by the phrase "He sorter sidled up to her and whispered." Analytic and synthetic are but relative terms and sometimes the synthetic form of expression is the simpler. To me at least, in the French line quoted above, *de la Tyrannie,* though analytic, presents to me in a blur, as through a glass darkly, what I see crystal clear in the synthetic possessive *Tyranny's* by which I have rendered it.

As I have already said in another connection, German in its noun and Spanish in its verb are at least as synthetic as Latin, spite of an evolution longer by two thousand years. That these languages with their rich flexional systems and their concords for gender, number and case are instruments more difficult in the use or less apt in the expression of the thought of Germans and Spaniards than English is for us is sheer assumption; and it were a peculiarly chauvinistic obsession to call German or Spanish languages of a lower type than English. In the estimation of the difficulty that attaches to learning and using a national tongue, no foreigner's opinion can possibly assess the difficulty for the native. As regards the adequacy of a language to express the thoughts of its native users, it may be said that no type of language has ever been found inadequate. Homer's Nestor of the honied tongue with many flexions; Demosthenes with fewer; Cicero with his adjective cases and genders and his verb moods; Burke in a nearly flexionless English: who shall say that one of these commanded a language of less flexibility, a language less apt for the expression of thought, than another? Did Greek flexions hamper Demosthenes, restrict his thought? The appeal of Demosthenes to-day is in part due to Demosthenes, but in part to what used to be somewhat sentimentally called the genius of the Greek language. I can conceive of a Zulu approximating Demosthenes before a Zulu audience, but not of a Zulu Demosthenes whose appeal could reach me, unless he had been steeped in a Zulu literature accessible also to me.

Language is the expression of thought, but it is more, it is the prompter of thought. A word is not only what it means, it is all that it suggests by association. Rhyme, often decried as a meretricious embellishment, has helped modern poets to many a richer thought. Metaphor so completely triumphs over the worn and literal expression that it may be said to do our thinking for us. But metaphor continually wanes in the word till all becomes literal again. The metaphors of a foreign language, of Greek and Latin, where they differ from our own, freshen thought. Other freshening of metaphor is—slang. Demosthenes, the heir of all his ages, put his thoughts in Greek, but Greek no less put her thoughts in him. Man is the weaver but words are the yarn, and the yarn is delivered to him spun and dyed. Its strands are thought, its color emotion. The weaver has, in fact, little to do. He can at best but a little vary the conventional pattern, handed down to him by his unlettered ancestors. Or again, changing the figure, we may say that language carries its own organic ferments. These ferments set the poet's eye in a fine frenzy rolling. These ferments supply a vapor aglow with light that never was on land or sea. Some flash of a word —and we see the stars; some sputtering word—and our noses flinch.

AGRICULTURE IN THE HIGH SCHOOL

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THE proposition to put agricultural courses into the existing high schools may seem, at first thought, to be merely one of adding another subject to the curriculum. But experience shows that a curriculum may not be dealt with arbitrarily. To successfully inaugurate this subject it is necessary that study be made of its purposes and, more especially, of the adjustment of this to other high-school subjects.[1]

The subjects of the present curriculum most concerned in this adjustment are the sciences. These, "the most precious achievement of the race," are themselves comparatively new to the curriculum and the promise with which their introduction into the school was made has fallen far short of fulfillment, so that their status is at present far from a final adjustment.[2] And their close relation to the new subject, agriculture, makes the problem of the adjustment of all a single problem.

[1] "No study is worthy of a place in our program which has not commanded the full devotion of some master mind. All students must be introduced to the same civilization, and since all are human their several ways of approaching it will not be fundamentally different."—Brown, "The Making of Our Middle Schools," p. 440.

[2] "Science is the most precious achievement of the race thus far. It has made nature speak to man with the voice of God, has given man prevision so that he knows what to expect in the world, has eliminated shock, and above all, has made the world a universe coherent and consistent throughout."—Hall, "Adolescence," Vol. II., p. 544.

"This recognition of science as pure knowledge, and of the scientific method as the universal method of inquiry, is the great addition made by the nineteenth century to the idea of culture. I need not say that within that century what we call science, pure and applied, has transformed the world as the scene of the human drama; and that it is this transformation that has compelled the recognition of natural science as a fundamental necessity in liberal education."—Eliot, "Education for Efficiency," p. 37.

"I can not help feeling . . . that we have not yet succeeded in so organizing the sciences as instruments of general education as to fulfill the high expectations which some of us formed for them nearly a quarter of a century ago. There can be little doubt that the sciences of nature and of man, properly organized and presented as educational instruments, are destined to be classified as true humanities."—Butler, Address of Welcome, A. A. A. S., 1906.

"It seems to be a fact that the sciences, although dealing in knowledge of matters of the greatest immediate interest, and although concerned with the most elemental of all trainings . . . are still of mediocre efficiency as factors in general education."—Ganong, "Botanical Education in America," A. A. A. S., 1909.

The strength of the agriculturists' argument for the inauguration of courses in the schools has usually pertained to the immense economic significance. But the successful teaching of agriculture in the school along with the traditional courses depends, like all the rest, upon its being regarded and developed as a humanistic subject as well. It will have to "make good" pedagogically if it is to have a permanent place.[3] But it is also likely that pedagogy will have to recognize some new educational values before the subject can be considered in good standing by schoolmen. When educational ideals include the highest ideals of social efficiency the economic will, of course, be included. But until there is a recognition of something more than economic ideals there may be danger of the industrial reform getting in the way of educational progress, to the ultimate detriment of both.

A usable pedagogy is necessary to the solution of this problem. If pedagogy does not afford the principles and terms with which to treat the subject it is a sign that we need a new pedagogy.[4] Those who seek unity in education should insist that the "science of education" proceed to attack the problem with such means as it possesses. The result may be worth as much to education as to agriculture.

Without guiding educational principles the common mistake regarding this subject is to suppose that agricultural materials have inherent qualities which determine how they should be marshaled in the course. The result is the confusing variety of mechanically graded topics which secondary courses in agriculture present. As a matter of fact any purely agricultural theme will have phases which might be appropriate for any grade. The thesis here maintained is that the child's mind and body, rather than the materials, should be the controlling factors that determine all courses of study and that in the high school these must first, in this case, determine the organization of the sciences. For the

[3] "In the study of the concrete problems of education, we need a guiding principle; we need a formula that will cover every case that is presented; we need to know what education means in its simplest terms. Having such a principle we shall have a basis for interpretation—a criterion, perhaps, for approval or condemnation. Lacking such a principle, our results will be the merest empiricism, valuable it may be as separate facts, but totally inadequate to the needs of constructive effort."—Bagley, "The Educative Process," p. 3.

"Experience in teaching, covering several years in graded-school work, in an academy, and in a normal school, leads to the conviction that no subject requires more sound knowledge of the principles of pedagogy than does the subject of agriculture."—Abbey, "Normal School Instruction in Agriculture," p. 9.

[4] "New and fundamental concepts regarding educational principles are now needed which square with centralized and systematized industry."—Carlton, "Education and Industrial Evolution," p. 13.

"If pedagogy or education is to be permanently ranked among the sciences, it must find data in addition to that furnished by cultural imperatives and psychological investigations."—Carlton, "Education and Industrial Evolution," p. 18.

only features of agriculture that have pedagogic cohesion are the sciences involved.

Presented as they have been without any experience in their utilization having been afforded, high school sciences have not kept pace with educational needs. The fault seems to be that the student has been held too rigidly to the accuracy of an accumulated knowledge with too little experience with the method of its acquisition.[5] Pure science can be but imperfectly appreciated by the adolescent who still retains his dominant childish interest in the use, rather than the organization and structure, of things.[6] And if science *could* be taught as pure science its destructive tendency, striking as it does at the root of authority, is of questionable propriety where it does not at the same time furnish a philosophy of life. It is especially necessary under a rational government, such as ours, that it be made humanistic.[7] And humanistic science is applied science.

The purposes of high school agriculture, therefore, await the reform of the high school sciences; and a reform in the direction of applied science is evident to many science teachers who have no special interest

[5] "Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than the effective method of inquiry into any subject-matter. . . .

"Only by taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry, does one ever get a knowledge of the method of knowing. Because participation in the making of knowledge has been scant, because reliance upon the efficacy of acquaintance with certain kinds of facts has been current, science has not accomplished in education what was predicted for it."—Dewey, "Science as Subject-matter and as Method," A. A. A. S., 1909.

[6] "What the pupil is unable to use at any time can not be taught him most economically and efficiently at that time."—O'Shea, "Dynamic Factors in Education," p. 41.

"Then (in adolescence) . . . come the need of utilities, applications to machinery, hygiene, commerce, processes of manufacture, the bread-winning worth of nature knowledge, how its forces are harnessed to serve man and to produce values. Contrary to common educational theory and practise, the practical, technological side of science should precede its purer forms."—Hall, "Adolescence," Vol. II., p. 153.

[7] "An interpretation of humanism with science, and of science with humanism, is the condition of the highest culture."—Symonds, "Culture."

"As our schools grow more national they should also grow more humanistic. The older humanism was devotion to . . . an abstract ideal. The newer humanism of the schools can not well dispense with the best that the older humanism had to offer. But it will cease to be abstract. . . . The best that the school can do to guard them (youth) against self-centered commercialism, is to awaken their enthusiasm for some ideal good, which has power of appeal to the imagination. . . . We may look to see . . . a new humanism, leaning more and more on science, mindful of the past, patriotic in the present, and looking hopefully forward to the larger human interests."—Brown, "The Making of Our Middle Schools," p. 463.

in agriculture. The biologists, especially, are gravitating toward the use of the familiar things with which agriculture must deal.[8] If the agriculturists do not take advantage of this it will be their own fault. For if the scientists are to assume that part of the burden for the sake of the sciences, such "loss of jurisdiction" over their subject should not be taken amiss by the agriculturists, who may rest assured that the others have no means of cheating so as to achieve their "disciplinary" results wthout thereby doing that which is best for agriculture. Only in making the two phases of work complementary is agriculture securing a permanent place in the course. It may be that keeping the two interests uncorrelated will not only result in the continued decadence of high school science, but will also keep the subject of agriculture pedagogically outside the course of study, however much pains may be used to print it in.[9]

Agriculture in the high school will bear one of three relations to the fundamental sciences, namely, it will be taught before the related sciences are taught, or while they are being taught, or after they have been taught.

The success of agriculture in the high school depends upon its being made of such dignity as to challenge the powers of the better students.[10] And the better students will not be attracted to a subject that is long kept in its elementary stages.[11] There is more to lose than to gain in

[8] "I often wish that the phrase 'applied science' had never been invented. For it suggests that there is a sort of scientific knowledge, of direct practical use, which can be studied apart from another sort of scientific knowledge, which is of no practical utility, and which is termed 'pure science.' But there is no more complete fallacy than this. What people call applied science is nothing but the application of pure science to particular classes of problems. It consists of deductions from those whose general principles, established by reason and observation, constitute pure science. No man can safely make these deductions until he has a firm grasp of the principles; and he can obtain that grasp only by personal experience of the operations of observations and of reasoning on which they are founded."—Huxley, "Science and Culture," Chap. IV.

[9] "In every case correlation has been successful, when the instructor was sufficiently versed in his own subject and the kindred subjects to know when and how to bring the two together to the best advantage."—Abbey, "Normal School Instruction in Agriculture," p. 29.

"Relate the school to life, and all studies are of necessity correlated."—Dewey, "The School and Society," p. 107.

[10] "The highest type of spontaneous, whole-souled activity can not be developed about trifling or worthless things."—Hodge, "Nature Study and Life," p. 23.

[11] "If a child at any particular epoch in his development is compelled to repeat any fixed form of action belonging to a lower stage of development, the tendency will be for him to stop at that point, and it will be difficult, if not impossible, to get him up on to a higher plane. . . . Thoroughness in the pursuit of any study in the elementary school may result in cessation instead of promotion of mental growth."—Harris, "Educational Creeds of the Nineteenth Century," pp. 39–40.

attempting to popularize the subject by writing all of the science out of it. If it is not based upon the fundamental sciences it is not secondary but elementary, and, as such ignores the genetic stages of development usually represented by the high school adolescent.[12] Therefore, if agriculture is to be made a secondary school subject it must be put on a secondary plane—that is, it must be made scientific by the utilization of the fundamental sciences.[13] It should not be divorced from the high school sciences in order to precede them.

The deferring of the agricultural work in the high school until after the underlying sciences have been mastered will be at the very imminent risk of starving the peculiar vocational interest upon which its success depends. Investigations as well as experience show that the interest in vocation is born in adolescence and that the manual vocations normally precede the others.[14] It is a maxim of education that to develop a useful instinct it should be exercised and directed during its nascent period.[15] However judicious and far-sighted the plans of the teacher may be regarding the student's high school course, neither the student nor his parents may be safely left indefinitely in the dark regarding them. The average student in the high school should see a generous amount of purpose in all of his work and have the benefit of such experiences as are to be gained only by applying it to its purpose, even though it mean, from the viewpoint of the teacher, a compromise of his science.

Prescribing high school science work to precede the agriculture

[12] "When he (the pupil) has completed his eighth year, he should have a well-developed sympathy with agricultural affairs and he should have a broad general view of them. Entering the high school he will then be able to take up some of the subjects in their distinctly scientific phases."—N. E. A. Committee on Industrial Education in Rural Schools, pp. 44–45.

[13] "It is the business of secondary education to raise all subjects which it touches to the plane of science, by bringing all into the point of view of organizing principles."—Brown, "The Making of Our Middle Schools," p. 4.

[14] "In almost all great men the leading idea of life is caught early."—Eliot, "Education for Efficiency," p. 28.

"Until the instincts of construction and production are systematically laid hold of in the years of childhood and youth, until they are trained in social directions, enriched by historical interpretation, controlled and illuminated by scientific methods, we certainly are in no position to locate the source of our economic evils, much less to deal with them effectively."—Dewey, "The School and Society," p. 39.

[15] "If a nerve center is not exercised properly during its nascent period, it will be arrested in its development, for it loses its plasticity when the wave of ripening moves past it to other centers. . . . The absence of appropriate stimulus during the growing period is for the most part irremediable; and this results, as I have already intimated, not only in the arrest of this particular function, but it influences other functions by interfering with the readiness of association between centers that can become connected only through the undeveloped one. . . ."—O'Shea, "Dynamic Factors in Education," p. 151.

means either the perpetuation of a form of science instruction that has proved a failure in the high school or it means a reformed science, such as many teachers are now advocating, that introduces industrial applications. If the latter kind is contemplated it should be unnecessary to provide for it again in the agricultural course, for to admit that it can not be so utilized is to take all of the meaning out of the reform. If the former kind is contemplated, such students as can not appreciate "pure science" however elementary, may not be expected, after organizing a science in its more perfect form, to profit by any attempt later to open the subject and reorganize it in a less perfect form for agricultural or other utilitarian purposes, as an addendum, loosely attached and unessential, which must deal with drosser materials. The period for such organization is past for the student who can appreciate the science in its more perfect form, while those who might have profited by the compromised science will have been long since eliminated. Thus would both subjects suffer from the divorcement and postponement of agricultural instruction. The conclusion is that agriculture is not supplementary, but complementary, to the fundamental sciences in the high school.

In the days of pre-evolutionary thought, when learning was all a matter of authority, it was quite natural to think of form as dictating function, and formal knowledge monopolized the schools. The acceptance of the doctrine of evolution was a recognition of the fact that function dictates form.[16] According to the present conception the best teacher is that one who does not have the two very far separated in time.[17] In order that the high school science be properly taught it is necessary that the teacher have a ready knowledge of its function and that it be carried to its application while the subject is first being presented and is yet in the formative stage in the student's mind.[18]

The technique and terminology of pure science are the only adequate technique and terminology of applied science. The only difficulties which the student of agriculture meets are scientific difficulties.[19] It would be strange indeed if such difficulties might be better dealt

[16] "As structure follows function, experience in function must have been first in race history."—Baldwin, "Mental Development, Methods and Processes," p. 64.

[17] "As far as possible the study of form and function should go together."—Bailey, "The Nature-study Idea," p. 49.

[18] "The application in some form should always follow the generalization. The pupil should learn from the start that knowledge as it exists in the form of laws, principles, rules or definitions is utterly valueless, unless, directly or indirectly, it can be carried over into the field of practise."—Bagley, "The Educative Process," p. 303.

[19] "Any attempt to 'cut out' the 'impractical' parts invariably results in the inefficient functioning of the remainder. Short courses that aim to give only the essentials, fifth-rate colleges and normal schools that educate you while you wait, are sufficiently damned by their own products."—Bagley, "The Educative Process," p. 233.

with dissociated from the sciences to which they pertain.[20] So far as the two are related, the purposes of science can not be antagonistic to those of agriculture and it is better for the accomplishment of the reform toward vocational education to let the sciences bear their share of the burden of time and responsibility and have the same "charged to their account" while profiting as they will by the inclusion of the latter.

Should agricultural materials and principles be utilized for the purpose of teaching the sciences, and the student progressively pursue his science beyond the ability of agriculture to give any direct benefit, the operation of constantly rejecting the unessential and reconstructing with the (apparently) essential for the purpose of perfecting organization is a mental operation quite familiar to educators and is observed in daily practise by good teachers in all subjects. It is a characteristic merit of the "scientific method" and the "spiral plan," and is generally recognized as the natural order of mental growth. Thus most of the knowledge acquired in school is but transient in its value—a scaffolding for the erection of a more perfect structure.[21] It is not the agricultural work considered as knowledge so much as the right kind of training in science which its inclusion alone insures that makes it the best means of preparation in science for any collegiate course or for any general educational purpose.

But the fundamental sciences can not be depended upon to give a complete treatment of the subject of agriculture as it should be treated in the high school.[22] Where manual skills in technical processes are

[20] ''In order to develop a subject well, . . . it is necessary to establish and maintain a favorable atmosphere for that particular field of mental activity, and this atmosphere is at its best only in the presence of students interested mainly in that subject; that is to say, there is no more favorable place in which the farmer may study chemistry than in company with others, not merely of his own kind, but of those who believe that chemistry is the greatest thing on earth.''—Davenport, ''Education for Efficiency,'' p. 103.

''Learning a business really implies learning the science involved in it. . . . A grounding in science is of great importance, both because it prepares for this and because rational knowledge has an immense superiority over empirical knowledge.''—Spencer, ''Education,'' Chap. I.

[21] ''Coarse, crude, rapid work must come before refined, delicate, painstaking work. . . . On the other hand, if we permit the child to take his own gait he will be likely to stop upon some low stage of development. . . . To keep him at coarse, crude work continually would be a serious mistake. We must set the pace for him.''—O'Shea, ''Dynamic Factors in Education,'' p. 168.

''The most he knows at forty will be learned out of school, and . . . the business of the school is to give him a good start.''—Davenport, ''Education for Efficiency,'' p. 76.

''All our industries would cease were it not for that information which men begin to acquire as best they may after their education is said to be finished.''—Spencer, ''Education,'' Chap. I.

[22] When I speak of teaching agriculture in our high schools, I mean agriculture. I do not mean nature study, nor do I mean that some sort of pedagogical

to be taught, or the quality of grosser products studied, independent class work must be provided throughout the course. Then there are certain scientific phases which must be pursued in class further than may be thought profitable to the science student, though the cases are not nearly so numerous as is generally supposed.[23] Such training must be provided largely by collateral courses and from students' projects carried on at their homes. And it is necessary that agricultural students who purpose to apply their knowledge to that vocation, be segregated late in the course for the treatment of the subject as whole, where its ideals may be developed and its various phases synthesized into an independent "science of agriculture."

Could it be known at what stage a young person's schooling is to cease, his best interests seem to dictate a previous substitution of immediately usable knowledge for much of that of merely "disciplinary" or "preparatory" value.[24] The practical difficulty of accomplishing such

kink should be given to chemistry or botany or even geography and arithmetic. Let these arts and sciences be taught from their own standpoint, with as direct application to as many affairs of real life as possible; but let chemistry continue to be chemistry. . . . Every high school that has a natural agricultural constituency of any considerable importance should put in a department of agriculture on the same basis as its department of chemistry.''—Davenport, ''Education for Efficiency,'' p. 126.

''A thorough grounding in the natural sciences is essential to thorough agricultural courses, but so long as the instruction is confined to the departments of pure science it has had, and will have, very little significance or importance to agriculture. . . .

''If the divisions of science were strictly adhered to we should have no such thing as agricultural science. . . . The present-day plan for the classification of agricultural knowledge and its formulation into courses of instruction . . . is based on the application in the natural divisions of agriculture, rather than on its scientific origin. . . . A proposal to return to the former basis of the primary sciences would find scant indorsement among men who have studied the pedagogics of agriculture.''—Editorial in *Experiment Station Record*, January, 1908, p. 402.

[23] ''The sharp distinction between preparation for college and preparation for life is fading out. . . . So far as general culture is concerned, preparation for a higher school, rightfully conceived, coincides with preparation for life.'' —Brown, ''The Making of Our Middle Schools,'' p. 438.

[24] ''Vocational training is to be postponed as long as possible. It is to rest upon the most extended general schooling which the individual can get.''—Brown, ''The Making of Our Middle Schools,'' p. 459.

''The human plant circumnutates in a wider and wider circle, and the endeavor should be to prevent it from prematurely finding a support, to prolong the period of variation to which this stage of life is sacred, and to prevent natural selection from confirming too soon the slight advantage which any quality may temporarily have in this struggle for existence among many faculties and tendencies within us. The educational ideal is now to develop capacities in as many directions as possible.''—Hall, ''Adolescence,'' Vol. II., p. 88.

''Vocational training ought not to be included in the six years that are sufficient for the elementary school course. . . .The grave error of the past has been to frame a school course on the hypothesis that every pupil was to go for-purpose in our mixed schools is not only the inability of foreseeing and planning for individual needs, but also in the inadequacy of funds and teachers to satisfy such needs. On the assumption that a high school course and no more is to be made available to every youth of the land, such needs, except for delinquents and defectives, may best be provided in the latter part of the high school course.

This would mean the utilization of agriculture so far as applicable in the teaching of all subjects and all kinds of students, with a gradual increase of the purely vocational phases for such students as have elected agriculture as a vocation. Thus would the correlated sciences be better treated for their own purposes without greatly disturbing the present system of accrediting schools and subjects, leaving the accrediting of the strictly vocational subjects of the same school to be dealt with separately. And it is necessary, if we would secure the right kind of science teaching as well as vocational courses with thorough foundations, to have them taught in the same school, else may the one be divorced from its source of strength and the other become no more than elementary and baldly utilitarian.

The "preparatory" value of the vocational side of the agricultural course may be considered apart from the reform of the sciences. It is this consideration that makes necessary the admission of educational values, until recently not recognized as such by schoolmen. First might be mentioned the significance to the young learner of testing by a muscular manipulation the objects of his environment. Such objects are of value as educational materials to the degree to which they call for necessary muscular adjustments similar to those which the race from the earliest times has experienced. Every sensation or thought, the psychologists affirm, naturally stimulates a motor adjustment which reinforces the original sensory or central impulse which originated the motion. And this "back stroke" from the muscle furnishing the unifying "*kinesthetic factor*" is a thing to be encouraged and not repressed, as has too often been done in school work.[25] In the earliest

ward in the most deliberate and amplest fashion to the study of the products of the intellectual life, regardless of the basis of his own economic support."—Butler, "Training for Vocation and for Avocation," *Educational Review*, December, 1908, pp. 472–474.

[25] "We have lately become convinced that accurate work with carpenter's tools, or lathe, or hammer and anvil, or violin, or piano, or pencil, or crayon, or camel's hair brush, trains the same nerves and ganglia with which we do what is ordinarily called thinking."—Eliot, "Education for Efficiency," p. 38.

"Every mental state is a fusion of sensory and motor elements, and any influence that strengthens the one tends to strengthen the other also."—Baldwin, "Mental Development; Methods and Processes," p. 440.

"No serious thought is possible without some voluntary effort, and no emotion ever arises without inducing some form of action."—Judd, "Psychology," p. 66.

years of childhood this need is most urgent, but may be regarded as always necessary in the nascent stages of any instinct. The instincts that pertain to vocation are born in adolescence, and agriculture, whether as a means or as an end, furnishes ideal materials and situations with which to work.

Akin to this kinesthetic factor is the value to the young of discovering and exercising his power of *control* over natural forces. Hitherto much of the work of the school has trained a passive contemplation of the things which concern an education. Here is a subject that incites to action and rewards in a material way the efforts of the youth to take a hand in directing the outcome. He thus gains a much-needed training in his power to get results and produce something of value to society.[26]

There is an educational factor of great and peculiar value known to our pioneer grandparents as *hardship*, but which we prefer to think sufficiently covered by the term *responsibility*. The educational value of responsibility has long been known, but to create situations for its exercise is an unheard of thing in education.[27] Perhaps it will never be possible to prescribe experiences that can be as valuable as the real crises of life, nor to be able to prejudge the ability of youth to arise to the occasion when the crisis comes. But if the attempt is to be made by the school to develop a sense of responsibility for the successful issue of an undertaking—and who shall say what the school may not undertake for the good of the young—certainly no one who has ever made the investment which even a small agricultural undertaking entails, and which can neither be delegated nor hastened, can deny the possibilities of this subject.

"James, Hall, Dewey, Mosso, Wundt, Baldwin and others are preaching a new gospel. They are saying that the child's thought is never dissociated from his muscles; that every idea has a motor aspect; that mind is in one sense a middle term between the senses and the muscles; that it functions for the purpose of guiding conduct; that an idea is not complete until it is realized in action. . . .

"Viewed from the psychological standpoint it appears that muscular experiences are essential to the gaining of clear, definite, effective ideas in the world." —O'Shea, "Dynamic Factors in Education," pp. 27–29.

[26] "Properly thou hast no other knowledge but what thou hast got by working: the rest is all a hypothesis of knowledge; a thing to be argued in schools, a thing floating in the clouds, in endless logical vortices, till we try and fix it." —Carlyle, "Past and Present; The Blessedness of Work."

"The pupil must learn what nature is by trying what he can do with it; thus he measures it in terms of his own strength and skill, and discovers how it can be manipulated; and it is this experience that holds vital knowledge, and that enlists genuine interest."—O'Shea, "Dynamic Factors in Education," p. 52.

[27] "One of the last sentiments to be developed in human nature is the sense of responsibility . . . in the development of which our carefully nurtured and protected youth of student age . . . have had little training."—Hall, "Adolescence," Vol. II., p. 415.

Lastly, there are the unequaled opportunities of a *sociological* or *missionary* nature which come oftenest to one possessing practical knowledge and which if taken advantage of make him truly altruistic. Hitherto the real if not the admitted purpose of education has been the good of the educated, however much society, as a whole, may have profited from its educated members. But it is coming more and more to be recognized that no feature of an educational system, supported at public expense and whose single aim is citizenship, can be defended that does not contribute directly to social efficiency.[28] Social efficiency includes all that may be appropriate to the most utilitarian phases of industrial education, but it includes a good deal more. Racial betterment must be the compelling motive. On the final test of social efficiency "he that is greatest among you shall be your servant." [29]

The evaluation of these hitherto unassumed school functions is, to him who insists that everything done in the school be assigned its proper "preparatory" value in credits of admission to higher institutions, the difficult end of the problem of the adjustment of agriculture to the course of study. The purpose of the high school is to undertake them and do them to the best of its ability, leaving it to the college and university to worry over their pedagogical classification and estimation.[30]

[28] "Effort for the production of property is ethical, and the moment the child engages in it he places himself on the side of law and order in the community."—Hodge, "Nature Study and Life," p. 30.

[29] "No matter how full a reservoir of maxims one may possess, and no matter how good one's sentiments may be, if one have not taken advantage of every concrete opportunity to act, one's character may remain entirely unaffected for the better. . . . A character is a completely fashioned will, and a will . . . is an aggregate of tendencies to act in a firm and prompt and definite way upon all the principal emergencies of life. . . . Every time a resolve or a fine glow of feeling evaporates without bearing practical fruit is worse than a chance lost; it works so as positively to hinder future resolutions and emotions from taking the normal path of discharge. There is no more contemptible type of human character than that of the nerveless sentimentalist and dreamer, who spends his life in a weltering sea of sensibility and emotion, but who never does a manly concrete deed."—James, "Psychology," Vol. I., p. 125.

"Education must seek to develop social action. It can take no account of possible thought or feeling which exercises no influence upon one's behavior. . . . The school can not have for its leading principle the improvement of the individual as an isolated being."—O'Shea, "Education as Adjustment," p. 95.

"Education for culture alone tends to isolate the individual; education for sympathy with one's environment tends to make the individual an integral part of the activities and progress of his time."—Bailey, "The Nature-study Idea," p. 63.

[30] "The interests of higher education will be better served by such prescription of college entrance requirements, and such tests of preparation, as will do most to vitalize instruction in the secondary schools."—Brown, "The Making of Our Middle Schools," p. 443.

THE LAWS OF ENVIRONMENTAL INFLUENCE

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THE relation of environment to heredity presents an issue that is becoming increasingly clear. I will state it in the words of Dr. F. A. Woods. "Experimentally and statistically, there is not a grain of proof that ordinarily environment can alter the *salient mental and moral traits* in any measurable degree from what they were predetermined to be through innate influences."[1] The premises of this statement lie in biology, while the conclusions must be verified by facts in social science. Dr. Woods implies that, for each virtue society holds dear and for each vice it condemns, there is a biologic character without the presence of which the virtue or the vice could not appear. This position controverts the evidence of social science as to the basis on which virtues and vices rest.

To discuss this problem, I must begin with the difference between the data of social and biologic sciences. Biology uses experiment and hence begins with germ cells: social science is based on observation and hence its data are the visible differences which the study of men affords. Both call their data characters, but as a loose terminology creates confusion, I shall call the germinal variations the biologist finds through experiment *characters,* while the visible differences in men open to observation I shall call *traits.* The problem then is what is the relation of biologic characters to visible traits? Is there a character for each trait, or do independent laws govern traits? To answer these questions, traits must be divided into two classes; mental traits are measured by differences in thought and expression while bodily traits denote external differences. Mental traits are again divided into social traits, which are impressed on individuals by society and physical traits which reflect brain activity.

Physical traits do not correspond to the virtues and vices emphasized by society. There are only five that have social significance—imitation, suggestion, sympathy, self-interest and will power. These have biologic antecedents. Social traits, however, change from environment to environment, from group to group and even from family to family. They are readily adopted, easily lost and have the marks of acquired characters. The motives for adopting a virtue come to the individual through social influences. The power in him leading to its acceptance is not due to some unit-character corresponding to the virtue in question,

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but is the result of will power exercised in this particular direction. An abstainer from alcoholic drinks has no unit-character distinguishing him from those who drink. He uses his will power to create an ideal of abstinence from which habits grow up, making it easy for him to reject liquor. His son, however, will have to go through the same process; nor is the effect diminished unless the temptation is reduced by the absence of opportunity. Bravery, honor, chastity, thrift, honesty and a host of other virtues are in the same position. They are due to one power manifested in many ways and not to many innate characters each manifested in one way. Can any one pick out the psychic or physical mark that accompanies these virtues? If not, it is more reasonable to assume that the virtues a man cherishes are due to the society of which he is a part and not to the germinal determinants that make up his heredity. The real difference between a virtuous person and a victim of vice is that the one has will power to resist temptation while the other lacks will power. The drunkard did not mean to become a drunkard, nor did anything in his make-up force him to become one. He merely wanted to enjoy himself and failed to exercise his will power in restraint of temptation. The same is true of the prostitute. There is no race trait separating her from other women. Lacking home restraints, she drifted into vice, with the result that she was excluded from all social relations except those of her occupation. Vice is not a physical abnormality, but the lack of will power or of a restrictive social environment. The negative of each virtue is a vice, and it appears when the contrasted virtue is not evoked. Both are social in origin and in neither case are there special unit characters except those involved in the expression of will power. A single determinant coupled with a favorable environment gives reality to all the virtues. The lack of will power plus temptation is vice; the growth of will power minus temptation is virtue. These two forces make the difference that exists between the good and the bad.

Criminal traits differ from virtues and vices in that they have a physical background. The study of degeneration carried on by Lombroso and his disciples shows that they are biologic characters. They represent, however, reversions and not creations. They are thus due not to alterations in the germ cell by which it gets more or different determinants, but to retardations in development by which a full expression of inherited traits is prevented. The criminal has had his growth checked, so that he expresses not the full power of his race, but the traits of this race at some earlier period. To hate, to envy, to be brutal are atavistic traits natural to his ancestors, but now suppressed by the full development of normal powers. Their sources are therefore the sources of retardation; they must be studied as examples of retardation and not of germ cell development.

The environment of a man changes not as he moves from place to place, but as his income is raised or lowered. A change from $10 to $20 a week alters radically the conditions under which a family lives and gives to its members other motives and temptations than those that moved them in their earlier period. Two contrasted conditions result. A condition of surplus where choices are large and a condition of deficit where physical wants are seldom met. Each of these states have visible effects that can be readily traced. A state of deficit affecting children results in defective bodily development. The child matures more rapidly and loses the plasticity of mind and body which better nourished children possess. This means the appearance of atavistic traits which in turn promote criminal tendencies. A state of deficit is thus the cause of crime and of those peculiarities that accompany the retardation of development. Families under its influence falling below the normal standard approximate in thought and character the condition of distant ancestors. Deficit and retardation are different phases of one group of tendencies. Deficit is the cause; retardation is an effect. The result is the increase of crime and the loss of moral tone.

The deterioration due to a deficit is not more marked than that due to a surplus. An animal eats freely and even gorges itself without injury because the energy to acquire food must always be kept active in order to assure survival. Men, however, separate action from enjoyment; those who are favored in income can expand their consumption without correspondingly increasing their activity. The constant stimulation of appetite and the overworking of organs to relieve the system of its load leads to morbidness and disease. It also results in the creation of toxic substances which poison the body and depress mental activity. These evils react on the will and reduce its power to control thought and activity. With the decay of will power the moral virtues are undermined. The victim of indulgence thus sinks into vice and drifts into evils that an active will power would have avoided. Morbidness, disease, auto-intoxication, a weak will and vicious inclinations appear when social conditions throw into the hands of individuals a surplus that permits a cessation of strenuous activity.

Surplus and deficit are thus equally dangerous. Those in want have their development retarded and suffer from the evils bound up with this condition. Those whose surplus permits satiety and idleness suffer with equal severity from a train of evils that flows from morbid conditions. Moral, vicious and criminal traits thus vary with objective conditions and are marks of bodily states that depend on the surplus and deficit of society. The result is the sinking of the race into a subnormal condition from which there is no relief until economic conditions are altered. Normality is increased by taking from the surplus of the prosperous and adding to the welfare of those injured by poverty.

It is not increased by an elimination which merely changes the character of defects without reducing their amount. Vices are the negative of will power: criminal traits are the negative of development. They are not independent characters corresponding to changes in the germ cell.

The main result of the preceding discussion is to show that the unit-characters of the germ-cell do not correspond to the moral and immoral traits made emphatic in social science. The biologic characters important in social science are few in number, of which will power is the only one on which the present progress of the race depends. Social traits correspond to the peculiar conditions in which society finds itself and they grow in number as the complexity of the environment increases. Chastity, thrift or temperance indicates desirable social conditions which are pictured in the ideal they create. There could be forty such characters with no biologic change except a growth of will power. Progress in man is due to concentration of energy. The central organs, the brain and its adjuncts, have grown at the expense of the terminal organs such as the hand, foot, teeth and jaw. More energy goes to the brain and less to the external structures of vital importance to lower animals. This concentration of energy results in the prolongation of childhood, the growth of psychic powers and the dominance of will over instinct. But at the same time it creates a deficit in terminal organs which forces them into a state of decay. The marks of these changes are the psychic effects revealed in thought and the regressive effects seen in terminal organs. A single biologic tendency could thus create all the difference that separates man from other animals.

We are now in a position to discuss the variations that create differences between parent and child. One source of difference is degeneration, caused by a surplus of nutriment. This clogs the system, produces morbidness and creates auto-intoxication. The final mark is a weak will. The lack of central control is prominent in degeneration and leads to many manifestations of which hysteria is an example. A second difference of parent and child is due to retardation. Each organism in its development repeats the history of its ancestors. An imperfect recapitulation means that the growth of the child stops short of the development of the normal ancestor. From this source many variations arise. A third difference between parent and child is caused by regression. As distinguished from degeneration and retardation, regression is only partial indicating real progression in unobserved parts. In man the terminal organs fail to come up to the standard set by earlier development. The central organs, however, are progressive and their growth is the real cause of the regression of terminal organs.

No terminal organ will attain its full development except under the stimulus of constant use. In a blacksmith's arm the stimulus causing its growth is in his mind and not in his arm. He wants certain goods and the way to get them is to use his arm as a smith. The positive side of his development is psychic through which a greater appreciation of goods arises. This leads to work; work involves exercise and exercise leads to growth of the arm. In the case of a musician the stimulus that develops the hand is in his appreciation of music. So long as the love of music persists the stimulus is present which arouses the peculiar growth in the arm. Instead therefore of a new modification in the germ cell being needed to perpetuate the modification of the musician's arm the germ-cell modification has already been made. It exists in the psychic variation creating the love of music. While this persists, the stimulus is present that forces the right growth in the arm. The arm of the musician as compared with that of a laborer is regressive but the stimulus that comes from a love of music keeps active a group of muscles and leads to their growth. There is a general terminal regression counteracted in specific cases by the stimulus due to the activity of central organs. This, I believe, will be found true of all cases purely regressive. They are the effects of progressive changes in the central organs. They should not be confused with degeneration and retardation which indicate a real backward movement.

The other ways in which parent and child differ are through injury and recovery. Any child may be injured in ways that will affect subsequent growth. So in turn he may be free from injuries of parents or, what is more important, his environment may be so modified that injuries to which they were subjected become less frequent or disappear. Ancestors may suffer injury from a disease like malaria or from a parasite like the hook worm for so long a time that the injury seems inherited. A change of environment, however, may prevent the injury and bring back the children to normal standards. Recoveries of this sort are as frequent as the injuries that depress; they need recognition in any scheme to present the differences between parent and child.

It may seem from the last paragraphs that I am getting over into biology where other persons are a better judge of the facts than I am. The change of attitude is, however, more apparent than real. The traits of men and the facts about degeneration were observed long before biology became a science. What biology has done is not to discover new traits, but to enable us to classify them and to show their causes. Only the most obvious facts of biology are needed for this purpose, and they are of importance not to help observation, but to point out remedies. That riches caused men to degenerate and that poverty retards the development of the poor are well-established facts.

They show that states of surplus and deficit affect not only moral traits but also create degeneration and retardation. Psychology, however, has added a clearly defined cause of non-development which had escaped notice. The growth of an organ depends partly on the direction given to growth by the unit characters of the germ-cell and partly to the use to which it is put. Even if the forces of the germ-cell are normal no organ will fully develop without constant exercise. Regression in an organ will take place if the stimuli to exercise are absent. These stimuli lie not in the organ, but in the brain cells. Mental activity may fail from three causes. Psychic traits may be inactive through degeneration: they may not develop because of retardation: or the environment may lack the elements that arouse their activity. In each of these cases the trouble lies in objective facts mainly if not solely of an economic nature. Regressions do not differ in their origin from degenerations and retardations. They all arise from defects in the environment and thus do not indicate changes in the unit-characters of the germ-cell.

A study of man should begin with his social nature and with the degenerate forces at work within him. These two problems run into each other because it is man's social nature that has stopped elimination. Society uses its nurture to keep the weak alive and hence improved conditions means not progress but degeneration. A second difference between men and animals arises out of the social classes which differences in income create. The poor are in this way subject to exploitation and held in the grip of want. Dr. Woods says men have choices and can escape their environment. This is in a degree true of the higher income levels but not of the poor. Their fate is as definite and as objective as that of any lower animal. Along with poverty goes physical retardation, and the two combined are responsible for the mass of traits associated with the poor. A full maturity depends on the stimuli that evoke activity and hence promote growth. These stimuli are psychic traits made active in men by contact with the economic environment. This means that wealth is needed to place around each family the proper objects to excite interest: without them the psychic powers are dormant and the physical are regressive.

The environment of a man is determined not by his geographical habitat, but by his income. The various income levels of society create as marked differences in men as differences in latitude do in animals. The influence of environment on man is therefore not less but different from the same influence on animals. All virtues and defects in men are environmental. The virtues are social; the defects are degenerations, retardations and regressions. Most observable traits come under these heads. They change with the environment and not with the germ cell. Only those changes that are really progressive can be attributed to the germ-cell. All other traits can be traced directly or indirectly to social or nutritive alterations. Heredity is the one power that can transform man into a superman and we must rely on it to reach this higher level. The actual problems we face to-day are those of degeneration. We must get rid of the subman before we can rise to the superman's level. The subman is made by environment as truly as the superman will be made by heredity. We must therefore act through objective agencies until the normal in men has been evoked. Are social traits acquired or natural? Is degeneration in man due to bad environment or to heredity? These are the problems which must be fairly faced and definitely solved before it can be justly claimed that man is freer from environmental control than are the lower forms of animal life.

THE RACE FIBER OF THE CHINESE

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OUT of ten children born among us three, normally the weakest three, will fail to grow up. Out of ten children born in China these weakest three will die and probably five more besides. The difference is owing to the hardships that infant life meets with among the Chinese. If at birth the white infants and the yellow infants are equal in stamina, the two surviving Chinese ought to possess greater vitality of constitution than the seven surviving whites. For of these seven the five that would infallibly have perished under oriental conditions of life are presumably weaker in constitution than the two who could have endured even such conditions. The two Chinese survivors will transmit some of their superior vitality to their offspring; and these in turn will be subject to the same sifting and the surviving two tenths will pass on to *their* children a still greater vitality. So that these divergent child mortalities drive, as it were, a wedge between the physiques of the two races. If, now, for generations we whites, owing to room and plenty and scientific medicine and knowledge of hygiene have been subject to a less searching and relentless elimination of the weaker than the Chinese, it would be reasonable to expect the Chinese to exhibit a greater vitality than the whites.

With a view to ascertaining whether the marked slackening in our struggle for life during the last century or two and our greater skill in keeping people alive has produced noticeable effects on our physique, I closely questioned thirty-three physicians practising in various parts of China, usually at mission hospitals.

Of these physicians, only one, a very intelligent German doctor at Tsing tao, had noticed no point of superiority in his Chinese patients. He declared them less enduring of injury, less responsive to treatment and no more enduring of pain than the simple and hardy peasants of Thuringia amongst whom he had formerly practised. Three other physicians, each of whom had practised a quarter century or more in China, had observed no difference in the physical reactions of the two races. I fancy their recollections of their brief student practise at home had so faded with time that they lacked one of the terms of the comparison. Moreover, two of these admitted under questioning that the Chinese *do* stand high fevers remarkably well and that they *do* recover from blood poisoning when a white man would die.

The remaining twenty-nine physicians were positive that the

Chinese physique evinces some superiority or other over that of their home people. As regards surgical cases, the general opinion is voiced by one English surgeon, who said, "They do pull through jolly well!" It was commonly observed that surgical shock is rare, and that the proportion of recoveries from serious cuttings is as high in the little poorly equipped, semi-aseptic mission hospitals of China as in the perfectly appointed, aseptic hospitals at home. Dr. Kinnear, of Foochow, recently home from a furlough in Germany, found that in treating phlegma of the hand he with his poor equipment and native assistants gets as good results as the great von Bergman working under ideal conditions on the artisan population of Berlin. The opinion prevails that under equal conditions the Chinese will make a surer and quicker recovery from a major operation than the white.

Many never get over being astonished at the recovery of the Chinese from terrible injuries. I was told of a coolie who had his abdomen torn open in an accident, and who was assisted to a hospital supported by a man on either side and holding his bowels in his hands. He was sewed up and in spite of the contamination that must have gotten into the abdomen, made a quick recovery. Amazing also is the response to the treatment of neglected wounds. A boy whose severed fingers had been hastily stuck on any how and bound up with dirty rags came to the hospital after a week with a horrible hand and showing clear symptoms of lockjaw. They washed his hand and sent him home to die. In three days he was about without a sign of lockjaw. A man whose fingers had been crushed under a cart some days before came in with blood poisoning all up his arm and in the glands under the arm. The trouble vanished under simple treatment. A patient will be brought in with a high fever from a wound of several days standing full of maggots; yet after the wound is cleaned the fever quickly subsides. A woman who had undergone a serious operation for cancer of the breast suffered infection and had a fever of 106°, during which her husband fed her with hard water chestnuts. Nevertheless, she recovered.

Nearly all are struck by the resistance of the Chinese to blood poisoning. From my note books I gather such expressions as "Blood poisoning very rare. More resistant than we are to septicæmia." "Relative immunity to pus-producing germs." "More resistant to gangrene than we are. Injuries which at home would cause serious gangrene do not do so here." "Peculiarly resistant to infection." "With badly gangrened wounds in the extremities show very little fever and quickly get well." "Women withstand septicæmia in maternity cases wonderfully well, recovering after the doctors have given them up." "Recover from septicæmia after a week of high fever that would kill a white man." No wonder there is a saying rife among the foreign doctors, "Don't give up a Chinaman till he's dead."

In the south where foot binding is not prevalent the women bear their children very easily, with little outcry, and are expected to be up in a day or two. Dr. Swan, of Canton, testifies that more than once on calling for a sampan to take him across the river he has been asked to wait a quarter or a half hour. By that time the mistress of the boat would have given birth to the child, laid it in a corner among some rags and be ready to row him across. In childbirth the woman attended by a dirty old mid-wife in a filthy hovel escapes puerperal fever under conditions that would certainly kill a white woman. In cases of difficult birth when after a couple of days the white physician is called in and removes the dead infant, the woman has some fever but soon recovers. The women, moreover, are remarkably free from displacements and other troubles peculiar to the sex.

Living in a super-saturated, man-stifled land, profoundly ignorant of the principles of hygiene, the masses have developed an immunity to noxious microbes which excites the wonder and envy of the foreigner. They are not affected by a mosquito bite that will raise a large lump on the lately come foreigner. They can use contaminated water from canals without incurring dysentery. There is very little typhoid and what there is is so attenuated that it was long doubted to be typhoid. The fact was settled affirmatively only by laboratory tests. All physicians agree that among the Chinese smallpox is a mild disease. One likened it to the mumps. Organic heart trouble, usually the result of rheumatic faver, is declared to be very rare.

It is universally remarked that in taking chloroform the Chinese rarely pass through an excited stage, but go off very quietly. From after nausea they are almost wholly free. One physician of twenty-five years' practise has never had a death from chloroform, although he has not administered ether half a dozen times. The fact is, however, they stolidly endure operations which we would never perform without an anesthetic. Small tumors are usually thus removed and in extracting teeth gas is never administered. Sometimes extensive cutting—*e. g.*, the removal of a tumor reaching down into and involving the excision of the decayed end of a rib—is borne without flinching. Only three physicians interviewed had failed to remark the insensibility of their patients to pain. Here, perhaps, is the reason why no people in the world have used torture so freely as the Chinese. This bluntness of nerve, however, does not appear to be universal. The scholars, who usually neglect to balance their intense brain work with due physical exercise, are not stoical. The meat-eating and wine-bibbing classes lack the insensibility of the vegetarian, non-alcoholic masses. The self-indulgent gentry who shun all activity, bodily or mental, and give themselves up to sensual gratification, are very sensitive to pain and very fearful of it. Some make the point, therefore, that the oft-noted dullness of sensibility is not a race trait, but a consequence of the involuntary simplicity and temperateness of life of the common Chinese.

One doctor remarks that at home it is the regular thing for a nervous chill to follow the passing of a sound into the bladder, whereas among his patients it seldom occurs. Another comments on the rarity of neurasthenia and nervous dyspepsia. The chief of the army medical staff points out that during the autumn maneuvers the soldiers sleep on damp ground with a little straw under them without any ill effects. I have seen coolies after two hours of burden-bearing at a dog trot shovel themselves full of hot rice with scarcely any mastication, and hurry on for another two hours. A white man would have writhed with indigestion. The Chinese seem able to sleep in any position. I have seen them sleeping on piles of bricks, or stones, or poles, with a block or a brick for a pillow and with the hot sun shining full into the face. They stand a cramped position longer than we can and can keep on longer at monotonous toil unrelieved by change or break.

But there is another side to the comparison. There is little pneumonia among the Chinese but they stand it no better than we do, some say not so well. There is much malarial fever and it goes hard with them. In Hong Kong they seem to succumb to the plague more readily than the foreigners. Among children there is heavy mortality from measles and scarlet fever. In withstanding tuberculosis they have no advantage over us. While they make wonderful recoveries from high fevers they are not enduring of long fevers. Some think this is because the flame of their vitality has been turned low by unsanitary living. They have a horror of fresh air and shut it out of the sleeping apartment, even on a warm night. In the mission schools, if the teachers insist on open windows in the dormitory, the pupils stifle under the covers lest the evil spirits flying about at night should get at them. The Chinese grant that hygiene may be all very well for these weakly foreigners, but see no use in it for themselves. It is no wonder, therefore, that their school girls can not stand the pace of American school girls. Often they break down, or go into a decline or have to take a long rest. In the English mission schools with their easier pace the girls get on better.

Here and there a doctor ascribes the extraordinary power of resistance and recuperation shown by his patients entirely to their diet and manner of life and denies any superior vitality in the race. Other doctors practising among the city Chinese insist that the stamina of the masses is undermined by wretched living conditions, but that under equal circumstances the yellow man has a firmer hold on life than the white man.

From the testimony it is safe to conclude that at least a part of the observed toughness of the Chinese is attributable to a special race vitality which they have acquired in the course of a longer and severer elimination of the less fit than our North-European ancestors ever experienced in their civilized state. Such selection has tended to foster not so much bodily strength or energy as recuperative power, resistance to infection and tolerance of unwholesome conditions of living. For many centuries the people of south and central China, crowded together in their villages or walled cities, have used water from contaminated canals or from the drainings of the rice fields, eaten of the scavenging pig or of vegetables stimulated by the contents of the cesspool, huddled under low roofs, on dirt floors, in filthy lanes, and slept in fetid dens and stifling cubicles. Myriads succumb to the poisons generated by overcrowding and hardly a quarter of those born live to transmit their immunity to their children. The surviving fittest has been the type able to withstand foul air, stench, fatigue toxin, dampness, bad food and noxious germs. I have no doubt that if an American population of equal size lived in Amoy or Soochow as the Chinese there live, a quarter would be dead by the end of the first summer. But the toughening takes place to the detriment of bodily growth and strength. Chinese children are small for their age. At birth the infants are no stronger than ours. The weaker are more thoroughly weeded out, but even the surviving remnant are for a time weakened by the hardships that have killed the rest.

I would not identify the great vitality of the Chinese with the primitive vitality you find in Bedouins, or Sea Dyaks, or American Indians. This early endowment consists in unusual muscular strength and endurance, in normality of bodily functions, and in power to bear hardship and exposure. It does not extend to immunity from disease. Subjected to the conditions the civilized man lives under savages die off like flies. The diseases that the colonizing European communicates to nature men clears them away more swiftly than his gunpowder. Entrance upon the civilized state entails a universal exchange of disease germs and the necessary growth of immunity. Now, it is precisely in his power to withstand the poisons with which close-dwellers infect one another that the Chinaman is unique. This power does not seem to be a heritage from his nomad life of five or six thousand years ago. It is rather the painful acquisition of a later social phase. It could have grown up only in congested cities, or under an agriculture that contaminates every growing plant, converts every stream into an open sewer, and fills the land with mosquito-breeding rice fields. Such toleration of pathogenic microbes has, perhaps, never before been developed and it certainly will never be developed again. Now that man knows how to clear away from his path these invisible enemies, he will never consent to buy immunity at the old cruel price.

To the west the toughness of the Chinese physique may have a sinister military significance. Nobody fears lest in a stand-up fight Chinese troops could whip an equal number of well-conditioned white troops. But few battles are fought by men fresh from tent and mess. In the course of a prolonged campaign involving irregular provisioning, bad drinking water, lying out, loss of sleep, exhausting marches, exposure, excitement and anxiety, it may be that the white soldiers would be worn down worse than the yellow soldiers. In that case the hardier men with less of the martial spirit might in the closing grapple beat the better fighters with the less endurance.

In view of what has been shown the competition of white laborers and yellow is not so simple a test of human worth as some may imagine. Under good conditions the white man can best the yellow man in turning off work. But under bad conditions the yellow man can best the white man, because he can better endure spoiled food, poor clothing, foul air, noise, heat, dirt, discomfort and microbes. Reilly can *outdo* Ah San, but Ah San can *underlive* Reilly. Ah San can not take away Reilly's job as being a better workman; but, because he can live and do some work at a wage on which Reilly can not keep himself fit to work at all, three or four Ah Sans can take Reilly's job from him. And they will do it too, unless they are barred out of the market where Reilly is selling his labor. Reilly's endeavor to exclude Ah San from his labor market is not the case of a man dreading to pit himself on equal terms against a better man. Indeed, it is not quite so simple and selfish and narrow-minded as all that. It is a case of a man fitted to get the most out of good conditions refusing to yield his place to a weaker man able to withstand bad conditions.

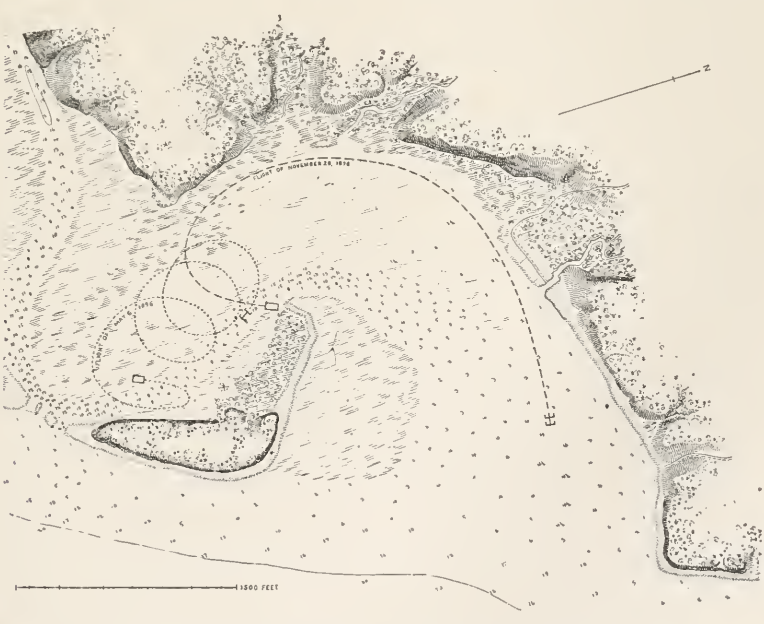
Of course, with the coming in of western sanitation, the terrible selective process by which Chinese toughness has been built up will come to an end, and this property will gradually fade out of the race physique. But for our time at least it is a serious and pregnant fact. It will take some generations of exposure to the relaxing effects of drains, ventilation, doctors, district nurses, food inspectors, pure water, open spaces and out-of-door sports to eradicate the peculiar vitality which the yellow race has acquired. During the interim the chief effect of freely admitting coolies to the labor markets of the west would be the substitution of low wages, bad living conditions and the increase of the yellow race for high wages, good living conditions and the increase of the white race.

THE PROGRESS OF SCIENCE

LANGLEY MEMOIR ON MECHANICAL FLIGHT

In the development of mechanical flight the United States has taken an honorable place both in theory and in practise. The work of Langley, Chanute and the Wright brothers can not be paralleled by any other nation. While in many directions we have done more than our share in mechanical invention, it has often happened that we have depended on Great Britain, France and Germany for scientific principles. But Langley was an eminent physicist and Chanute a leading engineer. It is interesting to know how far their achievements in aeronautics were based on mathematics and physical research and how far on empirical trials. The Langley "Memoir on Mechanical Flight," just published by the Smithsonian Institution, gives full details in regard to the work done by Langley and under his direction. The first part of the volume was in the main written by him in 1897; the second part, dealing with further experiments with the small models and with the large aerodrome, has been written by Mr. Charles M. Manly, who became assistant in charge of the experiments in 1898.

In 1891 Langley announced as the result of experiments carried on through previous years that machines could be constructed which would give such a velocity to inclined surfaces that bodies indefinitely heavier than the air could be sustained upon it and moved through it at a great speed. As a result of experiment and theory it was proved that one-horse power



Path of Aerodrome Flights, May 6 and November 28, 1896, near Quantico, Va., on the Potomac River.

Aerodrome in the Air during its Flight on May 6, 1896.

would propel and sustain in horizontal flight at a velocity of about forty miles an hour a little over 200 pounds. Langley's experiments were in the main made with a whirling-table which forces the model to move in horizontal flight and at a fixed angle. In 1887, however, he began experiments with free-flying models at the Allegheny Observatory, following Pinaud in using twisted rubber as motive power. Some forty models were made, but while, as Pinaud had shown, a small toy could be made to fly for a few seconds, the motive power was inadequate for a larger machine or a longer flight.

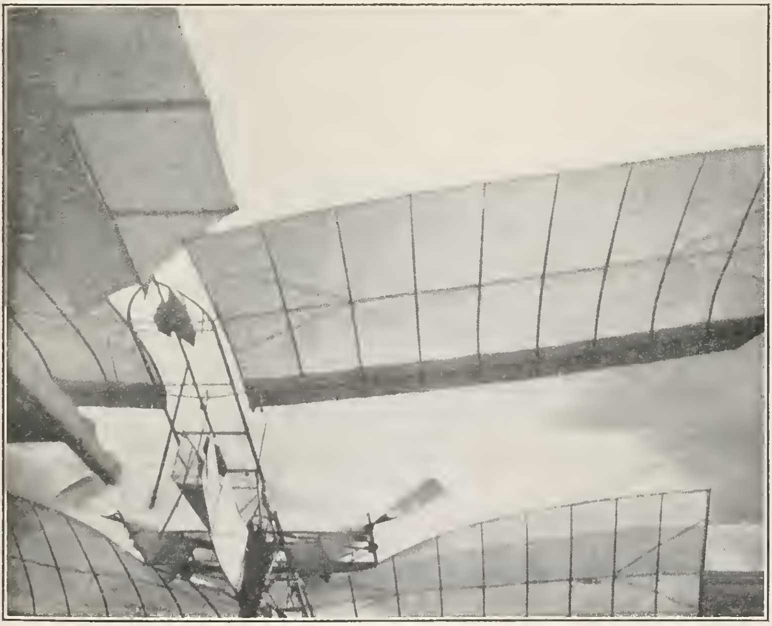
In 1891 Langley began the construction of a steam engine. Daimler had invented the internal-combustion engine in 1885, but its possibilities were not at first realized, and it was necessary to wait for the development of the automobile to demonstrate the remarkable combination of power and lightness in an engine which has made possible the contemporary aeroplane. After innumerable experiments a steam engine was constructed weighing about six pounds and of approximately one-horse power. An aerodrome, chiefly of steel, weighing, apart from fuel and water, about twenty-four pounds, was launched on the Potomac River on May 6, 1896, and flew for over half a mile. It alighted with safety and performed a second flight on the same day. This was a performance of great historic interest. The paths of the aerodrome on May 6 and again on November 28 are here reproduced, as also an instantaneous photograph of the aerodrome in the air, which bears a remarkable resemblance to a contemporary picture.

In 1898 the board of ordnance and fortifications of the war department appropriated $50,000 for experiments with a man-carrying aerodrome. Langley was at first indisposed to complete the work which he had carried so far, believing that might be left to commercial enterprise. It was, however, undertaken with the assistance of Mr. Manly, who now describes the results in this memoir. The great difficulty, as before, was with the engine. A New York builder could not supply the

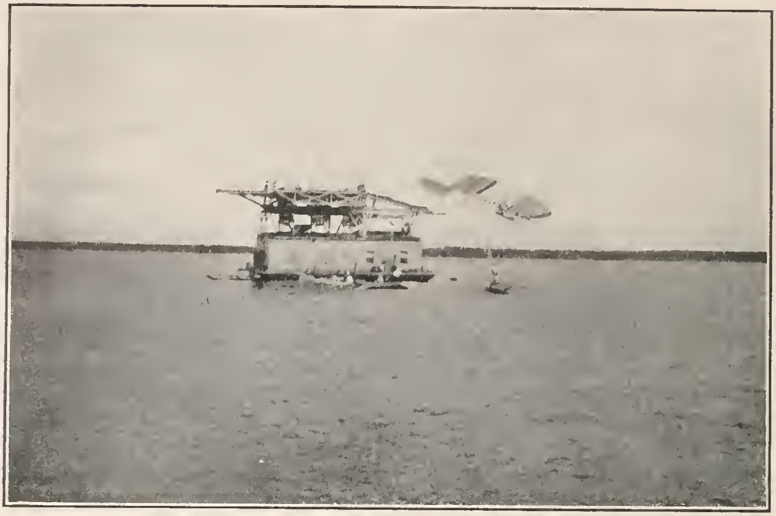
AERODROME NO. 5 ON LAUNCHING-WAYS.

gasoline engine for which he had contracted; no European builder thought it possible to supply a twelve-horse power engine weighing as little as 200 pounds. Mr. Manly at the end of the year 1901 had succeeded in constructing an engine of fifty-horse power, weighing about 200 pounds.

After long-continued experiments in adjusting the engine, the aerodrome was made ready for trial. The house-boat and launching gear caused innumerable difficulties but on October 7, 1903, at 12.20 P.M. the aerodrome, with Mr. Manly in control, was launched. The trial ended disastrously, owing to an accident by which a guy-post caught in the launching gear. Mr. Manly narrowly escaped drowning through entanglement in the wrecked machine. He showed great courage in again repeating the experiment under unfavorable conditions on December 8, when again the launching gear was at fault, and the aerodrome had no opportunity to demonstrate its power of flight. Owing mainly to ridicule in the newspapers and the fear of its effect on



FLIGHT OF LARGE AERODROME, OCTOBER 7, 1903.



FLIGHT OF LARGE AERODROME, OCTOBER 7, 1903.

Congress the army board was unwilling to continue the work. In the meanwhile the Wright brothers had begun their experiments with flying machines and in the year of the trial of the Langley aerodrome accomplished their first flight with a motor. In 1905 they remained in the air for half an hour, but it was not until 1908 that they fully demonstrated the practicability of sustained flight. Langley died on February 27, 1906, at the beginning of the era of mechanical flight to which his researches had so largely contributed.

THE ADDRESS OF THE PRESIDENT OF THE BRITISH ASSOCIATION

SIR WILLIAM RAMSAY presided over the recent meeting of the British Association for the Advancement of Science at Portsmouth, and, like many of his predecessors in the chair, made an address that is of very general interest. He gave a clear account of ancient and modern views regarding the chemical elements, laying, as is natural, much stress on the new discoveries in which he himself has taken such a leading part. It is not possible to review the marvelous story of the recent developments of chemistry more concisely than is done in the addr ss. It is of interest to note that Sir William Ramsay maintains, though rather incidentally, the validity of his experiments from which he concluded that the metal copper is converted partially into lithium by the energy radiated from radium, and that thorium, zirconium, titanium and silicon are degraded into carbon. It will be remembered that Madame Curie was unable to confirm these results.

Sir William Ramsay passes from the disintegration of the atom to the question of the available supply of energy, especially for Great Britain. He tells us that each Greek freeman had five helots who did his bidding, saving him from manual labor and giving Athens its preeminence in literature and thought, but that people in Great Britain are still better off, each family having twenty helots represented by the consumption of fifty million tons of coal annually. It is this coal which has given England its great wealth and commercial supremacy. At the present rate of increase of consumption the supply will be exhausted within 175 years, and there appears to be nothing

Memorial to Columbus erected in the Union Station at Washington, D. C.

to take its place. The best advice that Sir William Ramsay can give is to use it economically. He, however, calls attention to the forestry systems of Germany and France, and the efforts in this country on behalf of conservation. He reminds us of the enormous quantity of energy stored up in radium and its constituents. If the energy of a ton of radium could be utilized in thirty years, instead of being evolved at its invariable slow rate of 1,760 years for half-disintegration, it would suffice to propel a ship of 15,000 tons, with engines of 15,000 horse power, at the rate of 15 knots an hour, for 30 years—practically the lifetime of the ship. To do this actually requires a million and a half tons of coal. We are told, however, that the production of radium will never surpass half an ounce a year. If, however, the elements which we have been used to regard as permanent are capable of changing with evolution of energy, and if some form of catalyzer could be discovered which would increase their slow rate of change, then a boundless supply of energy would be available for the human race. Sir William Ramsay says that it would be folly to consider seriously a possible supply of energy in an acceleration of the liberation of energy by atomic change; but he concludes the address with the remark that while radioactive substances are in all probability incapable of industrial application, apart from medicine, their study has shown us to what enormous advances in the concentration of energy it is permissible to look forward, with the hope of applying the knowledge thereby gained to the betterment of the human race.

THE DIRECTOR OF THE AMERICAN MUSEUM OF NATURAL HISTORY

Dr. Frederic A. Lucas, recently appointed director of the American Museum of Natural History, was born in Plymouth, Mass., in 1852. At the age of nineteen he entered Ward's Natural Science Establishment, a commercial museum for the preparation of natural history objects of all kinds. Here he acquired his first practical training in the preparation of natural history specimens, including the mounting of birds, mammals and other vertebrates, the preparation and mounting of skeletons and casts of fossils, and in time he became manager of the establishment. During his connection with the famous Rochester institution two of his colleagues were William T. Hornaday and Charles H. Townsend, and it is noteworthy that these three men who were working together thirty-one years ago should one after another have been called to direct the work of three of the most important institutions of the kind in this country if not in the world—the American Museum of Natural History, the New York Zoological Park and the Aquarium.

In March, 1882, Dr. Lucas was called to the United States National Museum as osteologist. He is to be credited with the assembling, preparation, mounting, classifying and labeling of the fine osteological hall of the National Museum. He was gradually promoted until in 1902 he was placed in charge of all the exhibits of the department of biology.

His admirable work in the National Museum and long experience in museum methods of preparation and exhibition, as well as his growing reputation as an investigator and writer, led to his selection as curator-in-chief of the Museum of the Brooklyn Institute of Arts and Sciences, where he had free play for his talents. Dr. Lucas's work in the Brooklyn Museum has been marked not only by great activity in the acquisition of specimens and collections but also by rare originality in the display of natural history objects, especially for the purpose of bringing out principles of zoology and classification in such a manner as to both attract and instruct all classes of visitors. He is practically the originator of the small but admirably arranged collection

Dr. Frederic A. Lucas,
Director of the American Museum of Natural History.

of vertebrates there, and no better nor more scientific installations of mammals are to be seen in any museum. The arrangement and labeling both from scientific and artistic standpoints are unique.

The especial purpose of the president and trustees of the American Museum of Natural History in the selection and appointment of Dr. Lucas as director is the advancement of the educational arrangement and exhibition of the vast collections which the museum has been acquiring from various parts of the world, especially during the past decade. In this field Dr. Lucas is recognized as the leading expert in this country. The trustees realize that the American Museum is very strong and well arranged in certain departments, while others lack sequence, and that either geographic, systematic or evolutionary sequence is necessary in order to give the collections their full educational value and effect.

SCIENTIFIC ITEMS

We regret to record the deaths of Dr. Francis A. March, professor emeritus of comparative philology and English literature at Lafayette College, of Dr. Thomas Dwight, professor of anatomy at Harvard University, and of Professor Franklin H. King, of Madison, Wis., known for his publications on agriculture.

Dr. E. A. Schäfer, professor of physiology at Edinburgh, has been elected president of the British Association, for the meeting to be held next year at Dundee, beginning on September 4. The meeting of 1913 will be held at Birmingham.

The annual Herter lectures will be delivered at the Johns Hopkins University on October 4, 5 and 6, by Professor Dr. Albrecht Kossel, of the University of Heidelberg, who was awarded the Nobel prize last year for his discoveries in medical chemistry.

Next year the American Geographical Society celebrates its jubilee, and in connection with this event a transcontinental excursion for the purpose of geographical study is planned, under the leadership of Professor W. M. Davis. The start from New York, by special train, will take place some time in August, and the excursion will conclude in October, its duration being six or seven weeks.

The South Australian Cabinet has decided to contribute £5,000 towards the cost of the Mawson Antarctic Expedition.

THE POPULAR SCIENCE MONTHLY

NOVEMBER, 1911

THE BERING RIVER COAL FIELD, ALASKA[1]

By GEORGE F. KAY

PROFESSOR OF GEOLOGY, STATE UNIVERSITY OF IOWA

Introduction

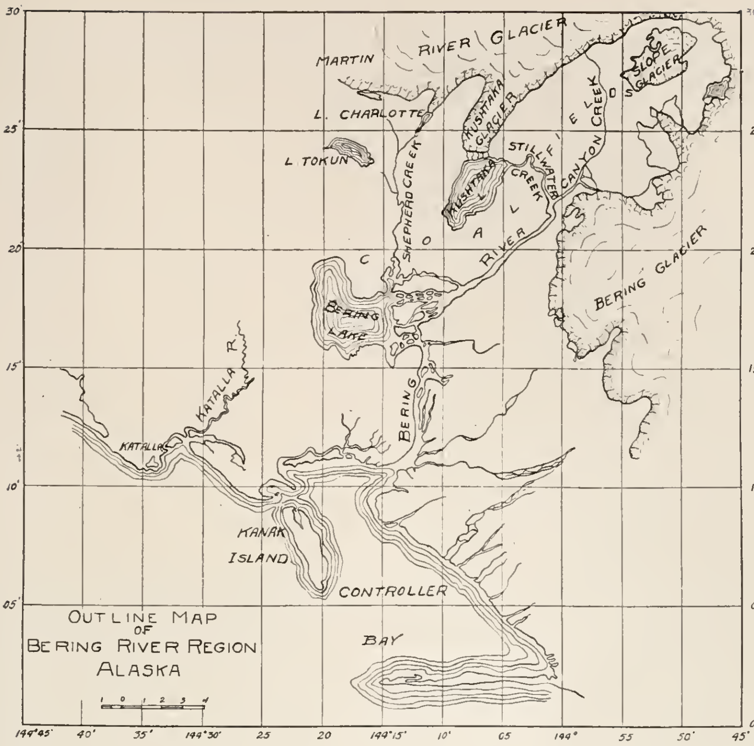
THE Bering River coal field lies a few miles inland from the north shore of Controller Bay, an indentation of the Pacific coast about 1,200 miles from Seattle. In this field are the Cunningham claims which received much publicity in connection with the Pinchot-Ballinger controversy. Much of the coal area is within the drainage basin of the Bering River. To the north of the field is the Martin River glacier with the lofty, snow-capped Chugach range of mountains beyond; to the east of the field and extending for many miles is the Bering Piedmont glacier.

The coal field is accessible by launch and small boat from the village of Katalla, a calling port for passenger steamships. From Seattle to Katalla by way of the "inside passage" is a voyage of seven or eight days; to Cordova, by the "outside passage" and thence to Katalla is a voyage of about five days.

No railroad has yet been built into the coal field, although several surveys have been made and some construction work has been done. Until a railroad has been completed and shipment has been made possible from the coast, the field will remain undeveloped. The chief difficulty in providing transportation facilities is the lack of good harbors on Controller Bay and adjacent parts of the coast. The waters are shallow and the coast storm swept. Many thousands of dollars have already been expended in an endeavor to form sheltered harbors, but it can scarcely be said that the efforts, thus far, have been successful. However, a deep water channel extending into Controller Bay and protected by islands from the ocean storms has recently been mapped by the Coast Survey. It would seem from present evidence that when a

[1] Sometimes named the Controller Bay Field or the Katalla Field.

Looking into the Head of Canyon Creek from the Hartline Claims.
Shows the Martin River Glacier and the Chugach Mountains.



thorough knowledge of the coast has been obtained the difficulties of securing suitable harbors will not be insurmountable.

The Copper River and Northwestern Railway Company, which has a railroad running northward into the interior from the splendid harbor of Cordova, has surveyed a branch line from this road to Katalla and thence to the coal field. The distance from the coal field to Cordova by this route is about 90 miles. Another route has been surveyed from the main line to the coal field by way of Charlotte Lake. By this route the distance to Cordova is only about 60 miles.

The area within which coal has been found extends in a southwest-northeast direction from Bering Lake to beyond Slope glacier, a distance of more than twenty miles. The width of the known coal formation is, in the northeastern part of the area, more than five miles, but the average of the field is considerably less.

The chief areas applied for in this field include the following: Controller Bay group. Pittsburgh group, Youngstown group, Cleveland group, Rathbone and Aurora groups, Pacific Coal and Oil Company group or English Company group, Cunningham group, Chezum group, Wardell group, Hartline group, Alaska Petroleum and Coal Company group, Willoughby group, the claims of the Portland Alaska

Anthracite Coal Company, the Alaska Anthracite Coal Company, the McKenzie Anthracite Coal Company, the Carbon Mountain Anthracite Coal Company and the Alaska Hard Anthracite Coal Company. Almost all the field was located prior to November, 1906, at which time these coal lands were withdrawn from entry by the government.

According to law each entry of 160 acres must have been made by an individual, or at most 640 acres by four individuals, and in the interests of the entrymen. By an act of 1906 entries made in good faith under the previous law were allowed to be consolidated into single holdings not exceeding 2,560 acres of contiguous land. Many of the claimants have done a considerable amount of development work, have had their lands surveyed, have paid in ten dollars an acre to the government, which is the requirement by law, and are now awaiting their patents.

The chief literature which has appeared on the Bering River field has been published in Bulletins of the United States Geological Survey. A complete list of the articles which have been written by members of the Survey and others may be found in the bibliography of Bulletin No. 442 of the Survey, by Dr. A. H. Brooks. Of all the published reports, that by Dr. G. C. Martin, in Bulletin No. 335, entitled "Geology and Mineral Resources of the Controller Bay Region," is the most exhaustive. Accompanying this report are very satisfactory geologic and topographic maps. In an article by George W. Evans, in the March, 1910, issue of *Mines and Minerals*, and also in an article by L. W. Storms in *Engineering and Mining Journal*, Vol. 90, p. 273, may be found maps showing the surveyed railway lines and the names and locations of the groups of claims which have been applied for in this field. A good Coast and Geodetic Survey chart of Controller Bay and adjacent parts of the coast is chart No. 8513.

The Geography of the Region

The topography of the area embraced by the known coal outcrops is rugged for a region of moderate relief. The elevations vary from a few feet above sea level at Bering Lake to somewhat more than 4,000 feet at the northeastern end of the field. The general trend of the ridges and mountains is northeast and southwest. A striking physiographic feature is the presence of broad valleys filled with alluvium and now occupied by comparatively small streams, except in times of flood. The numerous small valleys are V-shaped, often canyon like; the slopes from the divides are usually steep and broken by many gulches.

The largest stream is Bering River, which takes its rise in the lakes at the margin of Bering glacier. Its chief tributaries receive their waters from the abundant rainfall, and from the melting snows of Martin River glacier and its lobes. The tributary, Canyon Creek, flows from beneath the margin of the glacier; Stillwater and Shepherd Creeks drain Lakes Kushtaka and Charlotte, respectively. Both of these lakes are of glacial origin.

The precipitation of the region is probably in excess of 130 inches annually. The snow fall is very heavy. Above an elevation of 1,500 feet considerable snow is present even during the summer months.

The climate is not severe, the coldest weather recorded being 2° F. above zero. The average winter temperature is about freezing point; the average summer temperature between 50° and 55° F.

A Sill of Igneous Rock in contact with a Seam of Coal. Some of the coal has been converted into coke as a result of the intrusion. South end of Carbon Mountain.

Entrance to a Tunnel on the Purdy Claim West of Shepherd Creek.

The slopes are usually timbered with spruce and hemlock to an elevation of more than 1,000 feet.

The Geology of the Region

The chief rocks of the coal field consist of indurated sediments of Tertiary age and unconsolidated stream deposits, abandoned beaches and morainal material of Quaternary age. Associated with the Ter-

Davis Camp on Canyon Creek. These buildings are on the claims of the Alaska Coal and Petroleum Company.

Looking toward Slope Glacier from the Hartline Claims. It shows the structure of the coal-bearing rocks in this part of the field.

tiary sediments in the northeastern part of the field are narrow dikes and sills of diabase and basalt which are either Tertiary or post-Tertiary in age. The morainal deposits extend beyond the present limits of glaciation only a few miles.

The Tertiary sediments have been divided by Dr. Martin into three formations, namely, the Stillwater, the Kushtaka and the Tokun. The Stillwater is the oldest formation, and consists chiefly of sandstone and shale with a thickness of about 1,000 feet. The Kushtaka overlies the Stillwater conformably and is that part of the Tertiary which contains the beds of coal. It has a thickness of about 2,000 feet made up of coarse arkose, sandstone, shale and beds of coal. Complete sections

Part of the Cunningham Claims. Taken from divide west of Kushtaka Glacier.

Overlooking First Berg Lake and Bering Glacier from the Green Claims.

of the formations are not well exposed, and hence the number of seams of coal is not well known. The evidence suggests more than a dozen seams, varying in thickness from 6 inches to more than 35 feet. The Tokun formation overlies the Kushtaka conformably and consists of about 2,500 feet, chiefly of sandy shales, but containing also, sandstone and a subordinate amount of limestone. All the evidence thus far found indicates that the Stillwater formation is marine, the Kushtaka, non-marine, and the Tokun marine.

The Structure of the Region

The structure of the rocks of the coal field is, in general, monoclinal, the most prevalent strike being northeast; the dips are usually steep to the northwest. The main topographic features of the region have a general northeast-southwest trend, and are related in a broad way to the structure. But detailed study of small areas within the field emphasizes very clearly that the structure is much more complex than is indicated by a general study of the field. This complexity is due to folding, to faulting, and in the northeastern part of the field, to associated igneous rocks. Apart from a few well-defined lines of faulting with northeasterly and southwesterly trend, there are many small faults running in various directions. Moreover, within small areas in the field the strikes and dips are often irregular. The rocks

View taken from Doughton Peak, looking to the left of the ridge running northward and named Carbon Mountain. Shows structure of the coal-bearing rocks.

are frequently very much broken and jointed, and slickensided surfaces, especially in the coal, are common.

This complex structure was produced by the intense crustal movements to which the rocks were subjected during late Tertiary or post-Tertiary time. Recent subsidence of the region is indicated by the presence of alluvial deposits, in places several hundreds of feet in thickness, in the broad valleys now occupied by comparatively small streams.

The Coal

The coal beds are restricted to the Kushtaka formation which has a known surface area of about 50 square miles. The evidence is fairly clear that an additional area of more than 20 square miles underlies the Tokun formation at varying depths. The coal beds are distributed throughout the thickness of the Kushtaka formation. Where sections

VIEW TAKEN FROM THE McDONALD CAMP ON THE EAST SHORE OF BERING LAKE, looking to the left of Katalla Valley on the opposite side of the lake.

of the formation are best exposed, more than a dozen seams of coal may be seen, but several of these are thin and unimportant. In places, the best coal beds have thicknesses of more than 25 feet of good coal; at many places beds exceeding ten feet may be seen. Owing to the complexity of structure and the small amount of development work it is impossible to correlate the coal beds in one part of the field with those of other parts, even when the outcrops are not widely separated. The thicknesses of the beds often vary greatly within short distances along both the strike and the dip. In some places the evidence suggests that the irregularities in thickness are due to movements, the coal having been squeezed into great pockets of irregular shape. More-

VIEW TAKEN FROM THE MOUTH OF CHARLOTTE LAKE, looking toward a lobe of Martin River Glacier.

Poul Point, extending into Bering Lake.

over, in some places there is a somewhat abrupt change from a bed of good coal of considerable thickness into coal of a much lower grade or into carbonaceous shale. In some places the movements have resulted in the coal being intimately mixed with the rocks of the roof and the floor. The roof and floor are most commonly of shale. One sometimes finds the roof to be of shale and the floor of sandstone, or *vice versa;* in a few places sandstone forms both the roof and the floor. The roof is frequently fractured to such an extent that in mining timbering will be necessary.

The coal of the region is of good quality, the best grade being anthracite, the poorest grade semibituminous. The average of 32 analyses of samples of coal taken by Dr. Martin so as to represent the coals of the whole field was as follows:

	Per Cent.
Total moisture	6.02
Volatile combustible	10.44
Fixed carbon	75.30
Ash	8.23
Sulphur	1.47

The fuel ratios of these coals varied from 3.61 to 15.88, the average being 7.78. The highest B.T.U. value was 15,574, the lowest 8,386 and the average of the 32 analyses was 13,174. The average analysis of 7 of the coals which were classed as anthracite was

	Per Cent.
Moisture	7.88
Volatile combustible	6.15
Fixed carbon	78.23
Ash	7.74
Sulphur	1.30

The semibituminous grade of coal is found in the southwestern part of the field, the anthracite in the northeastern. Between these two areas the grade of coal is intermediate between semibituminous and anthracite. The distribution of the grades of coal corresponds somewhat closely to the complexity of structure in the different parts of the field. The structure becomes more and more complex from the southwest toward the northeast. The grade of the coal has been made better with an accompanying complexity of structure.

The semibituminous coal has been shown to possess good coking properties.

A striking feature of the coals, and one which is likely to be a serious handicap to their utilization, is their crushed and sheared condition. In many of the surface exposures and in the tunnels, drifts and open cuts where development has been carried on, the coal is soft and friable. Even where fairly firm and unbroken masses of coal are found, they can be readily crushed. It is difficult to find large lumps of coal free from fractures and slickensided surfaces. During mining, such coal can not escape being badly broken, and the difficulties of shipping will be great. In the case of the anthracite, the crushed and friable condition is likely to seriously impair its market value. With regard to the grades of coal of coking quality the soft character may not be so serious in that the coal can be converted into coke before shipping. It is scarcely probable, in a region where the crustal movements have been so widespread and intense, that the coals below the zone of surface disintegration will be free from the crushed and fractured conditions so prevalent at and near the surface.

From Doughton Peak looking Northward to the Right of Carbon Mountain.
Shows the structure of the coal-bearing rocks.

View from Chezum Group, West of Canyon Creek, looking over Martin River Glacier to the Chugach Mountains beyond.

Gas has been found in several of the tunnels; hence, in mining, safety devices will be necessary.

Development

At more than 300 places within the field more or less development work has been done. But no extensive mining has been carried on. The most prevalent kind of work consists of small surface openings. However, more than 30 drifts or tunnels have been run with an aggregate length of more than 3,000 feet. The most systematic development work has been done on the Cunningham, the Controller Bay, the Eng-

View from the English Company Claims, looking over Lake Charlotte to the mountains beyond.

lish Company, and the Davis groups. On the Cunningham claims several long tunnels have been run. At the McDonald mine on the Controller Bay group is a working drift more than 600 feet long. On the claims of the English Company there are three tunnels with a total length of more than 900 feet. On the Davis group is a tunnel whose length is more than 500 feet. During the summer of 1910 the Davis group was the only one in the field upon which systematic development work was being carried on.

Looking Down Elk Creek, Hartline Claims.

Summary and Conclusions

The coals of the Bering River field are of good quality, and the tonnage is unquestionably great. But the probable amount of this coal which is available at present or will be available in the near future can not be stated with any degree of reliability. The conditions of occurrence are such that until extensive development has revealed many data at present unknown, an estimate of the available coal would be little more than a guess. In coal fields of somewhat simple structure fairly reliable estimates may be made of the available coal from a study of the outcrops, but in fields such as the Bering field, where the structure is complex, such estimates are of little value, and in fact may be harmful. The figures are likely to be overemphasized, and even misused, by those who are endeavoring to interest the investing public. In much of the Bering field the rocks are folded, faulted, jointed and crushed; the coal beds are known to vary much in thickness within short distances along both the strike and the dip; the coal beds in several places may be seen to change somewhat abruptly into carbonaceous shale, and in places they are intruded by igneous rocks. As yet, the beds in the different parts of the field have not been correlated, nor is it possible to state the number of beds which are workable. Moreover, when it is recalled that gas is present in the coals, that the region is one of abundant rainfall, that the snowfall is heavy, that the coals are in many places friable, that many difficulties and large expenditures are connected with the problem of railroad construction and the providing of docking facilities, one begins to realize how necessary it is to give full weight to these facts in reaching a conclusion as to the value of the field.

The opening up of this field would be a great boon to Alaska and to the states of the Pacific coast. The government should do all in its power to hasten development. In cases where the evidence shows that the entrymen have conformed to the law, the patents should be issued without delay. Moreover, the Alaskan coal land laws should be speedily revised. The existing laws are unsatisfactory in that they do not tend to encourage but rather to discourage development. Not until large sums of money have been invested in this field will it be possible to mine and ship the coal on a commercial scale.

INSECT PARASITISM AND ITS PECULIARITIES[1]

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IT is universally admitted that economic entomology, like such other branches of applied biology as medicine and sanitary science, is to a very considerable extent the strategics of our warfare with a host of parasites, which are forever endeavoring to destroy our bodies, our domestic animals, our food supply, our clothing and the very materials with which we construct our dwellings and on which we write or print our interpretations of the wonderful world in which we live. In other words, economic entomology is, to nearly all intents and purposes, merely that portion of applied parasitology which deals with insects. Naturally, therefore, the destruction of the insect parasites of man and of the plants and animals on which his very existence depends, must always constitute the basic interest of this science.

A vague notion of putting certain of the parasites themselves to some use in the struggle to which I have referred, seems to have been apprehended even in pre-scientific times and among primitive peoples. We have read of savage tribes, which, like monkeys, eat their hexapod ectoparasites. The Aztecs invented another use for these creatures, as we learn from a quaint work published many years ago by Cowan.[2] He cites the following story from Torquemada "respecting the revenue of Montecusuma which consisted of the natural products of the country, and what was produced by the industry of his subjects. During the abode of Montecusuma among the Spaniards, in the palace of his father, Alonzo de Ojeda one day espied in a certain apartment of the building a number of small bags tied up. He imagined at first that they were filled with gold dust, but on opening one of them, what was his astonishment to find it quite full of lice? Ojeda, greatly surprised at the discovery he had made, immediately communicated what he had seen to Cortes, who then asked Marina and Anguilar for some explanation. They informed him that the Mexicans had such a sense of their duty to pay tribute to their monarch that the poorest and meanest of the inhabitants if they possessed nothing better to present to their king, daily cleaned their persons, and saved all the lice they

[1] A lecture delivered at the Marine Biological Laboratory, Woods Hole, Mass., August 8, 1911. In preparing the lecture for publication several footnotes have been added and the concluding paragraphs have been rewritten.

[2] "Curious Facts in the History of Insects," J. B. Lippincott & Co., Philadelphia, 1865.

caught, and that when they had a good store of these, they laid them in bags at the feet of their monarch." A more scholarly, not to say more spiritual, use of parasites, seems to have been invented by no less a personage than the founder of the Dominican order of monks, since it is related in the same work "that the Devil, teasing St. Domingo in the shape of a flea, skipped upon his book, when the saint fixed him as a mark where he left off, and continued to use him so through the volume."

Although we may infer from such personal and therefore very trivial uses of fleas and lice as food, book-marks and taxes, that both saints and savages have occasionally endeavored to make their parasites subserve a useful purpose, it is only within very recent times that what may be properly called an *economic* use has been suggested for certain parasitic and predatory insects; namely, that of controlling the insects injurious to our crops, forests, domestic animals, stored foods and fabrics. The notion of using predatory beetles in destroying garden pests seems first to have occurred to Boigiraud de Poitiers in France in 1843 and in the following year to Antonio Villa in Italy.[3] The latter country also produced the two entomologists Rondani and Ghiliani, who, during the fifties and sixties of the past century, first suggested the use of parasitic insects for similar purposes. Since 1870 this suggestion has taken firmer hold of entomologists, especially in France, Italy and the United States, largely owing to the remarkable results achieved by Riley, Howard and their collaborators in our federal Bureau of Entomology. To mention only a single example, it has been found that the fluted scale (*Icerya purchasi*), so destructive to the orange, can be controlled by an Australian ladybird (*Novius cardinalis*), and this control has been successful in California, New Zealand, Cape Colony, Hawaii, Florida, Portugal, Italy, Syria and Egypt. The scale was accidentally introduced into all of these countries and in all of them the beetle, when in turn introduced, showed itself capable of preventing the pest from spreading and destroying the orange trees. This and many similar, though perhaps less striking, cases, have led entomologists to ransack remote regions of the globe for parasites to rear and turn loose on the noxious insects, which, after accidental introduction into our country, increase so alarmingly and do so much damage, owing, in great measure at least, to the absence of the parasites and other enemies that keep them in check in their native environment. The most elaborate experiment of this nature and one which is being followed with keen interest by all economic entomologists, is now being carried on at the Parasitological Laboratory at North Melrose, near

[3] For a fuller account of the work of these and other early promulgators of the use of predators and parasites in combating noxious insects, see Trotter, "Due precursori nell' applicazione degli insetti carnivori a difesa delle piante coltivate," *Redia*, V., 1907, pp. 126–132.

Boston. Here for several years past great numbers of parasites have been received from Europe and northern Asia, carefully reared and studied, and, when found to be sufficiently promising, liberated in the hope that they will multiply and eventually control the gypsy and brown-tail moths.[4]

The fact that such economic uses have been suggested for insect and not for any other parasites seems to imply that the former must be peculiar in certain important particulars. This I believe to be true and has led to the following considerations. That I have chosen to read them to you, who are primarily interested in the problems of zoology in its broadest sense, is due to a conviction on my part that many of the accounts of parasitism, even in the best of our zoological hand-books, are more or less one-sided and anthropomorphic, probably as a result of the stepmotherly treatment necessarily bestowed upon the insects in such treatises. Before I say more about the insects, however, I wish to make a few remarks on animal parasitism in general.

Parasitism is, of course, a form of "behavior," and may be described as one of several complex types of the reactions of organisms to the most important source of their energy, their food supply. Other reactions to this element of the environment are predatism, commensalism, scavengerism and mutualism. There is in the main sufficient consensus of opinion concerning the distinctions between these different phenomena. Predatory animals kill other animals and devour them wholly or in part. Parasites put other organisms in the position of "hosts" by living *directly* on their tissues in such a manner as not to cause their immediate death. The parasite thus draws *indirectly* on the food supply of another organism by permitting or compelling it to do the hard work of procuring the food and of converting it into much more accessible and much more easily assimilable compounds. The parasite may be said, therefore, to use its host as an instrument not only for procuring, but for predigesting, its food. The commensal also uses another animal as an instrument, but merely in gaining access to a food-supply which the latter has procured but has not yet assimilated. The scavenger, like the saprophyte among plants, may be described as a parasite of the dead, deriving its sustenance from decom-

[4] Excellent general accounts of the subject here touched upon are contained in the following papers: Marchal, "Utilization des Insects Auxiliaires Entomophages dans la Lutte contre les Insects Nuisibles a l'Agriculture," *Ann. de l'Inst. Nat. Agronom.* (2), VI., 2, 1907, 74 pp., 26 figs.; translation in part in Pop. Sci. Monthly, LXXII., 1908, pp. 352–370, 406–419; Silvestri, "Sguardo allo Stato Attuale dell' Entomologia Agraria negli Stati-Uniti del Nord America, etc.," *Boll. Soc. Agric. Ital.*, XIV., No. 8, 1909, 65 pp.; Howard and Fiske, "The Importation into the United States of the Parasites of the Gypsy Moth and the Brown-tail Moth," Bull. No. 91, Bur. of Ent., Dep. Agric., 1911, 312 pp., 73 figs., 25 pls.

posing animals or plants or from the excretions of the former. The mutualist, finally, as the name implies, lives in a condition of balanced energetic or nutritional cooperation with another organism.

Of all these types of reactions to the food supply, parasitism is far and away the most prevalent; so prevalent, in fact, that it may be doubted whether there is any animal that does not resort to it, at least during a brief portion of its life, even if this be only during the period when, as an egg, it is drawing its supply of food-yolk from its parent. That parasitism has been most frequently developed from predatism is certain, that it may occasionally have its origin in commensalism, mutualism or scavengerism is highly probable, that it can, especially when it affects a considerable portion of the life-cycle of an organism, develop into anything but a more extreme form of parasitism, is very doubtful.

It would be easy to show by the citation of many examples that parasitism is an extremely protean phenomenon, one which escapes through the meshes of any net of scholastic definitions in which we may endeavor to confine it. Nor is this surprising when we stop to consider its great prevalence and the fact that during the course of time the organic world, *pari passu* with its increasing differentiation, has become ever more and more heavily weighted with parasitism and mutualism. That this nutritive dependence of organisms on one another has been steadily growing during paleontological time is clearly seen in the comparatively recent development of viviparity in mammals and many other animals, in the development of the alternating generations of plants into a condition in which the gametophyte is parasitic on the sporophyte (gymnosperms and angiosperms) or the sporophyte on the gametophyte (ferns and mosses), in the increasing mutualistic relations between insects and angiosperms, in the enormous development of parasitism among the highest orders of insects, the Diptera, Hymenoptera, Coleoptera, Lepidoptera and Homoptera, which are not known to have existed before Jurassic and Triassic times, and even in many apparently more primitive parasites like the true lice, bird lice, bat lice, fleas and many tape worms, flukes and round worms, which could not have developed till after their mammalian and avian hosts had made their appearance. Social life, too, which is hardly more than a mixture of parasitism and mutualism, shows a similarly recent development. Man himself, with whom we do not commonly associate the idea of parasitism, although the term is derived from a certain type of man well known to the ancient Greeks, not infrequently displays an extraordinary variety of parasitic activities. As an embryo he is always entoparasitic, using his allantois in a manner that vividly suggests the root-system of a *Sacculina* attached to a crab. At birth he becomes a kind of ectoparasite on his mother or nurse, and throughout his childhood and youth he is commonly what might be called a family parasite, depending for his sustenance on his parents, brothers and sisters or remoter relations. At maturity, in addition to the possibility of becoming parasitic on his wife, he has a choice of many kinds of social parasitism. As a member of a trust, political party or legislative body, not to mention many other organizations and institutions, he may graft successfully on the community at large or on some particularly lucrative portion of it, and should he fail through these activities to store up a sufficient *corpus adiposum* in the form of a bank-account, he may parasitize, with advancing years and till the end of his days, on his own offspring.[5]

But the roots of parasitism may be traced even deeper within the very fabric of the organism itself. The theories of Roux and Weismann have made us familiar with the struggle among the parts of the individual organisms, *i. e.*, among its organs, tissues, cells and the components of its cells, a struggle in which these elements often grow and develop at the expense of other elements in a manner that can only be regarded as parasitic. The more modern theories of mutation and Mendelism, with their insistence on unit-characters and "factors," obviously admit of an interpretation in similar terms. We can even shift this interpretation to the psychic plane, where we find the fixed ideas, obsessions and monomanias behaving as so many processes which draw their sustenance from other psychic processes to such an extent that they may in the end not only dominate but destroy the whole personality.

Some of you will be shocked at this account of what we are in the habit of describing in very different language, for the same emotional reason that we all admire the tiger and the tiger-beetle and loathe the tape-worm and the louse, namely, because our instinctive horror of the parasites to which our species is so constantly exposed, prevents us even as twentieth-century zoologists from appreciating the extent to which all life, ourselves included, is saturated with parasitic proclivities. I fear, however, that this attempt to justify my shocking language will fail to convince some others among you, who will accuse me of being myself a host of one of the obsessions to which I have just alluded—of the parasitic obsession, namely, of the idea of parasitism. You will say that in thus subtilizing or volatilizing what has always seemed to be a concrete biological phenomenon, and in thus diffusing the concept

[5] Certain general aspects of social parasitism in man are admirably presented by Massart and Vandervelde in their work entitled "Parasitisme Organique et Parasitisme Social," *Bull. Sci. de France et de la Belg.*, XXV., 1893, 68 pp., and by Ross in Chapter XXVIII. of his "Social Control," Macmillan Co., New York, 1910. The conception of viviparity as a form of parasitism has been developed by Giard ("Sur la signification générale du parasitisme placentaire," *C. R. Soc. Biolog.*, 1897), Houssay ("La Forme et la Vie. Essai de la Methode Mécanique en Zoologie," Paris, 1900) and Faussek ("Viviparity and Parasitism," in Russian, *Russkoje Bogatswo*, 1893).

of parasitism over the whole organic world, I have not only distorted it beyond recognition, but have deprived it of any usefulness which it may have had. To such accusations I can only reply that I gladly concede that it is admissible for practical purposes to circumscribe parasitism by arbitrary names and definitions in special fields of biological, sociological and psychological study, but I must insist, nevertheless, that it is a very fundamental and far-reaching phenomenon, which, for theoretic and heuristic purposes, may properly be said to include any complex of vital processes, which maintain themselves at the expense of other vital processes, in the same or in other organisms, without reacting on these processes in a similarly sustentative manner. But let us return to the more conventional conception of the subject.

When an organism becomes parasitic it, of course, undergoes structural and physiological changes. These express themselves in the loss or modification of previously existing characters and in the acquisition of new characters. The amount of this loss, modification and acquisition depends, first, on the intimacy of relationship of the parasite to the host; second, on the nature of this relationship; third, on the time in the parasite's ontogeny when this relationship is established, and fourth, on the portion of the ontogeny which it covers. Ectoparasites, as we all know, are, as a rule, less modified than entoparasites, but each of these categories includes very different degrees of modification, according as the parasite is confined to a particular organ of the host or is capable of moving more freely over its surface or through its tissues. The habitus of a parasite is most profoundly influenced and characterized by the moment in its ontogeny when it joins its host, and especially by the length of the period during which this association is maintained. According as this association is coextensive with the parasite's life or merely for a briefer period, we may distinguish *permanent* and *temporary* parasites. The latter, again, may be divided into those that are free from their hosts only during larval or early life and those that are free as adults. To these three types practically all animal parasites can be referred. They are best represented by such forms as certain tape-worms and flukes, by such crustaceans as *Sacculina,* and by such insects as the Ichneumonidæ and Chalcididæ among Hymenoptera and the Tachinidæ among Diptera. Permit me to describe very briefly the salient peculiarities of a typical example of each of these groups.

The tape-worm is an excellent example of a permanent parasite. It produces an enormous number of very minute eggs, and either these or the singular embryos, known as onchospheres, which they contain, are passively swallowed by the host. The onchosphere passes from the alimentary tract into the tissues of the host and there becomes a bladder-worm. This, in order to become a sexually mature tape-worm, must enter the alimentary tract of a second host. The transfer is effected passively by the second, or definitive, devouring the first, or intermediate host. Both stages of the parasite exhibit extreme modification of structure, the second being characterized by an enormous development of the hermaphroditic gonads and of the alimentary surface, which is merely the integument, and is therefore in immediate contact with the food supply. To this type of parasitism we may also refer the Dicyemids, and many of the flukes and round-worms. In many of these cases the association with the host may be effected without any effort on the part of the parasite, and the small size, the enormous number and the method of distribution of its eggs are properly interpreted as so many direct and necessary adaptations to chance.

The Rhizocephalous crustacean *Sacculina,* which may serve as a paradigm of the second type, or that of temporary parasitism with free early ontogenetic stages, also produces an enormous number of minute eggs. These, however, develop into free-swimming Nauplii, which in turn become Cypris larvæ and as such seek out their Decapod or Isopod hosts. Owing to the activity and comparatively high organization of these larvæ, the element of chance in bringing about the host association, though still considerable, is not as great as it is in the tape-worm. When it has joined its host, the Cypris larva, through one of the most remarkable methods of development known to exist among animals, proceeds to undergo structural modifications so extreme that, without a knowledge of the earlier stages, the crustacean affinities of the organism would never be suspected. "In the adult state the body consists of two portions: a soft bag-like structure, external to the host, carrying the reproductive, nervous and muscular organs and attached to some part of the host's abdomen by means of a chitinous ring; and a system of branching roots inside the host's body, which spring from the ring of attachment and supply the external body with nutriment."[6] In *Sacculina,* as in the tape-worm, the gonads are hermaphroditic and reproduction takes place by a continual round of self-fertilization. To this type of temporary parasitism with free larval stage we may also refer the myzostomes and other parasitic annelids and the parasitic mollusks. In all these cases metamorphosis supervénes while the animal is still very small and hence *precedes* growth and the incidence of the modifications produced by the parasitic habit.

As an example of the third type or that of temporary parasitism with free adult stage, we may select the Ichneumonid Hymenopteron. The eggs are few in number and rather large and are deposited by the mother directly in or on the host, which is the larva of some other insect. The sluggish, bag-shaped parasitic larva, on hatching from the egg, feeds for some time on the blood-tissues and fat-body of the host, but is careful not to prevent the latter from moving about, procuring its food and growing to maturity. When it has reached this stage, how-

[6] Geoffrey Smith in the Cambridge Natural History, Vol. IV., p. 95.

ever, the parasite quickly destroys it by consuming its vital tissues. It then completes its own growth, pupates and eventually emerges as a very active, highly organized and beautifully colored fly, provided with a splendid nervous system, exquisite sense-organs and powerful locomotor organs in the shape of legs and wings. It is either a male or a female and, if of the latter sex, soon proceeds to place its offspring in immediate contact with the host. Although the larval *Ichneumon* exhibits modifications of structure almost as extreme as those of the adult *Sacculina,* these produce no effect on the organization of the adult insect. The association of the larva with its host is the work of the mother insect, a creature gifted with complex instincts that enable her to ferret out the host even in the most intricate concealment. The large size and small number of her eggs and her highly specialized method of oviposition indicate very clearly that chance, which plays such a rôle in the life-cycle of the tape-worm and *Sacculina,* has given way to an almost inevitable association of the parasite with its host.

Of course, the *Ichneumon* represents only one of many forms of parasitism among insects. I have chosen it because it is the most characteristic and most highly specialized. There are insects like the Strepsiptera and the Rhipiphorid and Meloid beetles which seem to combine the *Sacculina* with the *Ichneumon* type in that they produce many small eggs that hatch as very active triungulin larvæ and only later develop into legless, bag-like larvæ of the *Ichneumon* type. It is interesting to note that in the Strepsiptera the adult female prolongs the parasitic habit of the larva, while the adult Meloidæ or oil-beetles are rather sluggish and seem to show other after-effects of their larval life. There are also many insects, like the true lice and bird lice which are, to all intents and purposes, permanent parasites comparable with the ectoparasitic flukes, though they never exhibit such extreme modifications. And, finally, there are other animals besides insects that have parasitic larval and free adult stages, *e. g.,* the fresh-water mussels.[7]

Zoologists have naturally been deeply impressed by such wonderful parasites as the tape-worms, flukes and *Sacculina* and have regarded these as fine examples of degeneration or degradation. Many, indeed, have dwelt on these words in a manner which leaves no doubt that they are used in a purely anthropomorphic sense as implying deterioration or "an impairment of natural or proper qualities" in the parasites, notwithstanding Ray Lankester's assertion that "degeneration may be defined as a gradual change of the structure in which the organism becomes adapted to less varied and less complex conditions of life."[8] It is easy to trace the source of this anthropomorphism to the atrophy of the parasite's neuro-muscular system, a system by which we as intel-

[7] *Cf.* Lefevre and Curtis, "Reproduction and Parasitism in the Unionidæ," *Journ. Exper. Zool.,* IX., No. 1, 1910, pp. 79–115, 5 pls.

[8] "Degeneration," p. 32.

lectual beings necessarily set great store, and the hypertrophy of the alimentary and reproductive organs, which, notwithstanding their immense biological significance, have nevertheless been assigned a very inferior place in our scheme of ethical values. But parasites may properly be regarded as more advanced organisms than the predators, for they have not only had a more eventful phylogenetic career, but, during their long history, have learned to use other organisms in a very economical manner as instruments of nutrition. From a consistent biological point of view, therefore, and from one embracing insect as well as vermian and crustacean parasites, it is evident that the peculiar convergent complexions of these organisms should be attributed to *specialization.* "Degeneration" is properly a pathological term, and parasites, however pathogenic they may be, are, of course, no more pathological or diseased than predatory animals. There is some evidence to show that the myzostomes have persisted in their modern form since Silurian times, with a conservatism equalled only by that of their Crinoid hosts. If all the generations of these peculiar annelids have been pathological for millions of years, they should long since have disappeared from the waters of the globe, but we find that though many or all of the original species have doubtless become extinct, this was probably due simply to the extinction of their hosts, for nearly every extant species of Crinoid supports at least one species of *Myzostoma.* Moreover, if we regard parasitic modification as an expression of degeneration, we must suppose that such forms as the adult *Ichneumon* are produced by a post-larval regeneration. Apart from adding an unusual meaning to the word "regeneration," this fails to express the actual conditions correctly. The whole ontogeny of such insects is in reality very highly specialized, the adult representing in many particulars as great a departure from the primitive insect type as the larva, albeit in a very different direction. In discussions of this subject I would therefore substitute the words "parasitic specialization" for such terms as "degeneration" and "degradation." Together with these, another term, "retrogression," should be avoided, for the reason that the parasitic modifications of structure to which it is often applied can be more properly attributed to "arrest of development."

It will be seen from the foregoing discussion that the leading peculiarity of insect parasitism, at least in such groups as the Hymenoptera and Diptera, which are almost the only ones of value in controlling noxious insects, is *the restriction of the parasitic habit to the sluggish larva and the specialization of the free adult for the purpose of disseminating the species and of placing the coming generation in intimate contact with the host.* No one who observes one of our large, graceful Ichneumonids, such as *Thalessa lunator,* alighting on a tree-trunk and then conveying its greatly attenuated eggs by means of its long hair-like ovipositor through some three inches of hard wood into the burrow of a *Tremex* larva, the presence of which it has been able to detect by means of its marvelously acute sense-organs, can fail to appreciate the advantages of such a method of bringing a parasite to its host, rather than by the tape-worm's shot-gun method of scattering minute eggs about promiscuously, or by the *Sacculina's* almost equally haphazard method of employing minute, feeble, aquatic larvæ.

Another peculiarity of economic importance in the parasitism of Hymenopterous and Dipterous insects is its *highly predatory character,* for the voracious larvæ of these orders almost invariably kill their hosts.[9] Other forms, like the Strepsiptera, which permit their hosts to reach the adult stage, nevertheless destroy their gonads and thus decrease the reproductivity of the host species. In some cases, indeed, it is impossible to decide whether we are dealing with parasitism or predatism. The *Sphex,* that lays her eggs on caterpillars which she has carefully paralyzed, is commonly regarded as a predatory insect, but she is from another point of view, an even more specialized parasite than the *Ichneumon.* Her sting immobilizes but does not kill the active full-grown or nearly full-grown caterpillars, and her larvæ are careful to feed in such a manner as to spare as long as possible the life of their victims. We have here merely a further extension of the maternal instincts primarily devoted exclusively to bringing about the union of the parasite with the host, to a unique and effective preparation of the host's body for easier exploitation by the parasite.

A third peculiarity of economic importance in the Hymenopterous and Dipterous insects is their *pronounced tendency to confine their attacks to species of large, recently developed and eminently noxious groups,* such as the Lepidoptera, Coleoptera, Homoptera and other plant-destroying insects.

There are also a number of peculiarities some of which are of less practical but of no less theoretical interest. These, which I must consider very briefly in the limited space at my disposal, are the following:

1. The occurrence of *hypermetamorphosis* which is frequently exhibited by parasitic insects often of the most remote taxonomic affinities, such as the Proctotrypids, and certain Chalcidids (*Orasema* and *Perilampus*) among the Hymenoptera, *Mantispa* among the Neuroptera, the whole order of Strepsiptera, and the Meloidæ and Rhipiphoridæ among Coleoptera. The complication of development arises in all of these cases from an inability of the mother insect to find the host or at any rate to reach it during the proper ontogenetic stage, and

[9] It would seem that the death of the insect host is necessitated either by the relatively very large size of its insect parasite at maturity, when acting alone, or (in cases of polyembryony and simultaneous infestation by several individuals of the same species) to the equally considerable bulk of a number of small parasites acting together. The comparatively slight difference in stature between host and parasite is certainly one of the most remarkable peculiarities of insect parasitism.

hence from the need of an active and inquisitive first larval stage to supply this defect.

2. The prevalence of *hyperparasitism.* We may distinguish primary, secondary, tertiary, quaternary and even quinary parasites among insects, according to the principle of the "little fleas *ad infinitum.*" The numerical appellations in this series have been restricted to insects parasitic on other insects, although the primary parasites are really secondaries when they attack insects like caterpillars, since these are, of course, plant-parasites.[10]

3. The absence in parasitic insects of *hermaphroditism,* a phenomenon so prevalent among vermian, crustacean and annelidan parasites. Only one small group of insects is known to be hermaphroditic, namely, the Termitoxeniidæ, comprising a few genera of extraordinary flies that live in termite nests.[11]

4. The rare occurrence of *heterœcism,* or change of host, a phenomenon very prevalent among tapeworms and flukes. It has been developed, however, within apparently very recent times in such groups as the plant-lice and in certain myrmecophilous beetles of the genera *Atemeles* in Eurasia and *Xenodusa* in North America.

5. The increasing development of *viviparity* as seen in such a series of parasites as *Hemimerus,* which, according to Hansen and Heymons, develops within the ovary of its mother,[12] the larviparous Tachinidæ and Sarcophagidæ, the nymphiparous Hippoboscidæ, Nycteribidæ and plant-lice, and the Termitoxeniidæ which, according to Wasmann, are born practically as adult insects.[13]

6. The development of *polyembryony* among the Chalcidid and Proctotrypid Hymenoptera. Owing to the greatly increased reproductivity of these parasites through the formation of dozens or even hun-

[10] Fiske ("Superparasitism: An Important Factor in the Natural Control of Insects," *Journ. Econ. Ent.*, III., 1910, pp. 88–97) and Pierce ("On Some Phases of Parasitism Displayed by Insect Enemies of Weevils," *ibid.*, III., 1910, pp. 451–458) have distinguished between "hyperparasitism" and "superparasitism." The former term is defined by Pierce as "the normal attack of a parasite species upon another parasite species," whereas superparasitism "occurs when a normally primary parasite attacks a host already parasitized, and the result is that the latest comer generally attacks its predecessor." The distinction is important, but for the sake of brevity I have not introduced into the text.

[11] Wasmann, "Termitoxenia, ein neues flugelloses, physogastres Dipterengenus aus Termitennestern," 2 Pts., *Zeitschr. f. wiss. Zool.*, LXVII., 4, 1900, pp. 559–617, LXX., 2, 1901, pp. 289–298, and Assmuth, "Termitoxenia Assmuthi Wasm.; Anatomisch-histologische Untersuchung," Inaug. Dissert., 1910, 53 pp.

[12] *Cf.* Hansen, "On the Structure and Habits of *Hemimerus talpoides* Walk.," *Entom. Tijdskr. Arg.*, XV., 1894, and Heymons, "Eine Plazenta bei einem Insekt (*Hemimerus*)," *Verh. deutsch. zool. Gesellsch.*, 1909, pp. 97–107, 3 figs.

[13] *Loc. citato.*

dreds of adults from a single original egg by a process not unlike that employed in the egg-shaking experiments of our laboratories, this phenomenon, though restricted to comparatively few species, is nevertheless of considerable economic importance.[14]

7. The development of *social life* among insects. This, as I have shown on former occasions, has its origin both ontogenetically and phylogenetically in the parasitism of the offspring on the parent.[15]

Paleontology seems to show very clearly the conditions that have favored the enormous development of parasitism among insects especially within comparatively recent times. Some of these conditions are:

1. The *diminution in insect stature* which occurred in the late Carboniferous and during the Permian and seems to have been originally in great part an adaptation to increased reproduction and dispersal. Other things equal, a small animal will, for very obvious reasons, become a parasite more easily than a large one.

2. The *development of metamorphosis*. This was already clearly established in the earliest known insects, the Paleodictyoptera, which were predatory and amphibiotic like the may-flies of the present-day, living in the water during their apterous larval stages and spending their winged imaginal stage in the air. They show plainly the great peculiarity of insect development, *i. e.*, metamorphosis *succeeding* growth and not *preceding* it as in the crustaceans, mollusks and anne-

[14] The occurrence of polyembryony was first clearly recognized and thoroughly investigated by Marchal in *Eucyrtus fuscicollis* (''Recherches sur la Biologie et le développement des Hyménoptères Parasites. I. La Polyembryonie Spécifique on Germinogonie,'' *Arch. Zool. Expér. Gén.* (4), II., 1904, pp. 257–335, 5 pls., and an earlier paper: ''La dissociation de l'oeuf en un grand nombre d'individus distincts chez l'Encyrtus fuscicollis,'' *C. R. Acad. Sci. Paris*, CXXVI., 1898, pp. 662–664), although Bugnion (''Recherches sur le développement postembryonnaire, l'anatomie et les mœurs de l'Encyrtus fuscicollis,'' *Rec. Zool. Suisse*, V., 1891, pp. 435–534, 6 pls.) had previously studied the same insect. Silvestri has published several valuable papers on polyembryony, the most important being ''Contribuzioni alla Conscenza Biologica degli Imenotteri Parassiti. I. Biologia del Litomastix truncatellus (Dalm.),'' *Ann. R. Scuola Sup. d'Agric. Portici*, VI., 1906, pp. 1–51, 5 pls.

[15] Wheeler, ''Ants, their Structure, Development and Behavior,'' Columbia Univ. Press, 1910. Recently Holmgren (''Termitenstudien, I. Anatomische Untersuchungen,'' *R. Svensk. Vetensk. Handl.*, XLIV., No. 3, 1909, 216 pp., 3 pls., 76 text-figs.) and Escherich (''Termitenleben auf Ceylon,'' Gustav Fischer, Jena, 1911, 262 pp., 3 pls., 68 text-figs.) have accumulated much evidence to support the conclusion that the mutual attraction among the individuals and the development of the castes of the termite colony are due to the habit of these insects of feeding on the fatty exudates of one another's bodies and on that of their queens. This may also be true of ants and other colonial insects. A very similar method of feeding on the surface secretions of their host-ants is adopted by certain myrmecophiles (*Oxysoma, Attaphila* and *Myrmecophila*) and certain parasitic ants (*Leptothorax emersoni*).

lids. Dimly foreshadowed in this method of development are the more complete modern types of insect metamorphosis, which have their morphological origin, as we now know, in a doubling of most of the rudiments of the organs in the embryo. On hatching, one set of these rudiments develops immediately into the larval body, while the other set remains in abeyance in the form of minute germinal centers, or histoblasts, from which the body of the adult will be fashioned during the quiescent pupal stage. The higher insects are therefore beautiful examples of double personality, much more perfect examples of this phenomenon, in fact, than any that has been discovered in man. The larval insect is, if I may be permitted to lapse for a moment into anthropomorphism, a sluggish, greedy, self-centered creature, while the adult is industrious, abstemious and highly altruistic, concentrating its activities on reproduction and the dissemination of the species. Unlike ourselves, who are Mr. Hydes and Dr. Jekylls in varying degrees, for brief alternating periods in our lives, or even simultaneously, the youthful insect sows its wild oats with a vengeance as a glutton or even as an assassin and then experiences a change of heart and reforms for good and all.

Parasitism must have been very easily grafted on to such a sharply dichotomic method of development as that of the holometabolous insects, for the larvæ of the predators are already much inclined to sloth and gluttony when the food supply is abundant, and comparatively little modification would be required to convert them into parasites. But the same peculiarities of metamorphosis have also made the holometabolic insects ideal hosts. We have already seen that insects, as a rule, are themselves not only parasitic during larval life, but also prefer larvæ as hosts. It is not improbable that this is the primitive, and that parasitism on the egg, pupa or adult is a secondary, or derivative condition. The real secret of both host and parasite being larvæ lies in the peculiar significance of anabolism in this stage. The host accumulates great quantities of fats and proteids as a so-called "fat-body," which is of little or no immediate use to the organism itself, but is stored up to be utilized during metamorphosis. This fat body may, therefore, be devoured by the parasite and converted into its own fat-body without seriously injuring the host. Furthermore, the fact that the parasite, too, stores up its food in the form of a fat-body instead of at once turning it over to its gonads and becoming reproductive, accounts for the striking differences between the insect parasite, on the one hand, and the tape-worm and *Sacculina,* on the other. The few exceptions among insects, such as the female Strepsiptera, in which the food taken by the larval parasite from its host is soon turned over to the gonads and used for reproduction, leads to a permanent parasitism resembling that of the tapeworms or the adult *Sacculina.* The larva is at once arrested in its development and begins to reproduce by pædogenesis. We may conclude, therefore, that the existence of parasites of the *Ichneumon* type, with free, active and highly developed adults is rendered possible by an inhibition of gonadic growth during larval life; whereas parasites which begin to reproduce while still living with their hosts are thereby prevented from either leaving them or undergoing further morphological differentiation.[16]

3. A third primitive peculiarity of holometabolic insects, which seems greatly to have favored parasitism, is the astonishing *rapidity of their larval metabolism and growth* and the equally remarkable *quiescence of their pupal stages*. These have, of course, converted insects into the most wonderful opportunists, through enabling them to take advantage not only of the changing seasons and the very diverse physical conditions of our planet, but also of the most evanescent supplies of food, both living and in process of decomposition.

4. *Parthenogenesis* may also be cited as a widely prevalent phenomenon, which has been put to good use by parasitic insects. Like polyembryony, it has an economic significance, because it enables such noxious parasites as the plant-lice to multiply enormously under conditions that would preclude reproduction in non-parthenogenetic species, and for the same reason greatly assists many Hymenopterous parasites in checking the undue multiplication of these and other plant-destroying insects.

Although I may have had little difficulty in convincing you that parasitism is a very specialized kind of behavior, you will probably still be of the opinion that there is something inherently and radically wrong with animals that resort to it rather than to predatism, mutualism or some other means of maintaining their vital activities. It must, of course, be admitted that in becoming satellites of their hosts, parasites have renounced the primitive, wasteful and erratic freedom of the predator and are compelled to mould their activities on those of the host. This necessarily puts them in a condition of such abject dependence that their very existence as individuals and species is imperilled whenever they overstep that margin of vitality which the host,

[16] This singular ability of the insect to inhibit the development and growth of its gonads till adult life is not only significant in connection with the development of parasitism within the group, but is also of fundamental importance in the development of colonial life among all the social insects. In the worker castes of these organisms the inhibition of the gonads, except under unusual conditions, is simply prolonged into and throughout adult life. Perhaps in last analysis this inhibition is merely a special manifestation of the extraordinary independence of the insect soma and germ-plasm, as has been so beautifully shown in the castration and transplantation experiments of Oudemans, Meisenheimer, Regen and Kopeć. For a discussion of this subject see my paper, "The Effects of Parasitic and Other Kinds of Castration in Insects," *Journ. Exp. Zool.*, VIII., No. 4, 1910, pp. 377–438, 7 figs.

like every other healthy organism, can afford to sacrifice to the accidents of its environment.[17]

The parasite not only tends to restrict itself to the use of a particular host as a food-procuring instrument, but is also compelled to exercise the most exquisite care in the use of this instrument. From the very nature of the situation, therefore, parasitism is an extremely precarious type of behavior. But this is true also of all highly specialized behavior, that of biologists included, and points the way to, but does not constitute, the real difficulty with parasitism. This, I take it, is the suppression of the voluntary movements, which necessarily results from the intimate host relations, especially when these are confined, as is so often the case, to some one particular organ or tissue. It is not, therefore, the parasite's habit of taking something for nothing from another organism, that is so fatal, for all creatures, in matters relating to nutrition, find it more blessed to receive than to give, but the acceptance of the most important supply of its energy under conditions that preclude an exercise of the muscular and hence also of the sensory and nervous activities and restrict its vital activities to a round of assimilation, metabolism and reproduction. This unbalancing of functions is probably hastened by a kind of intraorganismal parasitism or "Kampf der Theile" in Roux's sense, the alimentary and reproductive tissues drawing their nutriment not only from the host but also from the more inactive tissues of the parasite's own body. That this torpor, or inactivity of the neuromuscular system is at the bottom of the peculiar disability of parasites is shown by many non-parasitic organisms, which have easy access to an abundant food supply consisting of dead or inorganic substances. Most plants and many invertebrates, such as the barnacles, and especially the scavengers among insects, exhibit essentially the same modifications as parasites. In fact, the larval stages of many insects that feed on carrion or decomposing animal and vegetable matter, are quite indistinguishable from parasitic larvæ. This and the further fact that plant-eating species are not generally regarded as parasites by entomologists have led to considerable confusion in certain accounts of insect parasitism.

While most parasites among the lower invertebrates have never succeeded in freeing themselves from the tyranny of the host relation and the fatal torpor to which it inevitably leads, this is, as we have seen, by no means true of the typical insect parasites. To the ontogeny of these organisms the dictum "once a parasite, always a parasite" most cer-

[17] Within this "margin of vitality" must also be included the reproductivity of the host species. Thus certain ants, like *Formica fusca*, throughout the north temperate zone, are able to survive the inroads of a number of parasitic ants (*Polyergus rufescens, Formica sanguinea, F. rufa, F. exsecta* and many allied species), largely on account of its great reproductive powers, coupled with an ability to live in the most diverse physiographic conditions.

tainly does not apply. That it is inapplicable to their phylogeny I am not prepared to say, although I am unable to think of any non-parasitic insects that show evidence of descent from parasitic species. There can be no doubt, however, that parasites are still able to give rise to new specific forms. This capacity is without doubt very feeble or languishing in the permanent parasites of the tape-worm and *Sacculina* types as compared with that of the insects. Indeed, there is much evidence to show that in insects, parasitism, far from interfering with the process of species formation, may actually have a tendency to favor or accelerate it. Sharp estimates the number of species of parasitic Hymenoptera on our globe at 200,000, and of this vast number probably 80,000 belong to a single family, the Chalcididæ, of which only some 6,000 species have been described. Another parasitic family, the Tachinidæ, belonging to the great order Diptera, seems to be in such an active stage of species formation that the most diligent and thoughtful students of the group flounder about in it with a dazed and almost ludicrous helplessness. And not only is practically the whole enormous group of moths and butterflies to be regarded as parasitic, but the same is true also of untold legions of plant-lice, scale-insects and beetles. Hyperparasitism, which may be regarded as a kind of permutation of parasitism, must also be mentioned in this connection, because it gives us a glimpse of the virgin fields which the holometabolic insects, owing to their peculiar method of development, are beginning to invade.

I believe that the foregoing discussion of the peculiarities of insect parasites adequately supports the view that these organisms are eminently fitted to function in controlling the depradations of injurious insects. That they can not be regarded as instruments of extermination is obvious from the fact that under natural conditions the complete extinction of the host species involves the destruction of the parasitic species, unless the later is able to live on more than one host. Although it is not improbable that during geological time such joint extermination of host and parasite has repeatedly occurred, we are unable to cite any case that has fallen under the observation of the entomologist. Purely local extermination of injurious hosts by their parasites has, however, been observed.

Before bringing my lecture to a conclusion two matters must be briefly discussed. One of these, which is mainly of theoretical interest, relates to the development of the parasite's association with its host, the other, of more practical significance, to the methods of greatest promise in the study of insect parasitism. We need not stop to consider cases of the tape-worm type which reach their hosts by chance. In the two other types which I have distinguished, we have the association with the host established through the initiative of the larval parasite itself (*Sacculina* type) or through the parasite's mother (insect type). While the former type does not seem to call for any special explanation, there seems, at first sight, to be something mysterious in the insect parasite, for when we see an adult organism, such as an *Ichneumon* coming from a distance—out of the blue, so to speak—and seeking out a concealed larva in which to deposit its egg, we are tempted to turn to some teleological explanation, such as is implied in the common conception of "instinct," or perhaps to something in the nature of a "divinatory sympathy" between parasite and host. Although such conceptions are necessarily anthropomorphic, I would not deny them a certain, albeit provisional, value. As biologists, however, we are fortunately in a position to suggest a simpler explanation. The intimate practical knowledge (*sit venia verbo*) which the mother *Ichneumon* possesses of the host, loses much of its mystery when we stop to consider that she has, during her own larval life, devoured just such an insect, for the same reason that we may be said to have an excellent practical knowledge of an orange after we have eaten it. The *Ichneumon* is therefore familiar with the location, feeling, odor and taste of the creature in which she will lay her eggs, if we make the not improbable assumption that the results of her own larval experience persist as mnemic factors, notwithstanding the profound morphological and physiological changes which she has undergone during metamorphosis. There would then be nothing surprising in her tropism-like reactions to the mechanical and chemical stimuli represented by the host larva and its immediate environment.

As the time at my disposal is nearly exhausted, I must bring my discussion to a close. Having made the pilgrimage to the American Mecca of experimental zoologists, I could hardly hope for salvation if I departed without at least saluting the Kaaba. This I can do most effectively, perhaps, by calling attention to the great need of experimental work in animal and especially in insect parasitology. Biologists, during the romantic period of Darwinism, made much of the parasites. These organisms, in fact, supplied them with no end of ammunition in defence of natural selection, the influence of the environment and the biogenetic law. Then came the period of morphological minutiæ with its tacit assumption that particles of a dead organism are vastly more interesting and illuminating than the whole of a living one. During this period the parasites were, of course, sectioned and studied in the same manner as other organisms, but, since it is impossible to explain a living whole by pulling it to pieces and sticking the inert fragments together again, parasitism, which is a process and not a thing, retained its ethological interest mainly for biologists who were engaged in the practical applications of their science.[18]

Now that we have reached the third period, or that of emphasis on experiment with the living organism as the best means of elucidating

[18] In support of this statement the reader may be referred to the following general articles on insect parasitism, written by well-known economic entomolo-

the life-processes, those of us who had the misfortune to live and exhaust our greatest enthusiasm during the romantic and morphological periods, can, I suppose, do nothing better with the meager remnant of our vitality than pray for breadth of sympathetic vision on the part of our younger, more numerous and more vigorous contemporaries. The splendid achievements of the investigators who assemble here every summer certainly whet one's desire to see experimental work of the same character accomplished in parasitology. A certain amount of simple experimental work on social parasitism in ants has been inaugurated by Wasmann and myself and continued with interesting results by Santschi, Emery, Viehmeyer, Donisthorpe and others, but more important work, having for its object the artificial production of individual parasites and such studies on the behavior of their descendants as those recently made by Kammerer on the offspring of Amphibia, whose breeding habits had been artificially modified, have not yet been undertaken. Here again, as in so many other cases, the botanists are blazing the trail for the zoologists. The familiarity of the former with grafting, which is merely an artificially induced parasitism, has led them to undertake interesting experiments, like those recently published by Pierce[19] and MacDougal and Cannon.[20] And although these experiments yielded less striking results than might, perhaps, have been expected, they nevertheless emphasize an important fact, which all biologists, except systematists and paleontologists, are too apt to overlook, namely, the extraordinary stability of specialized characters.

Experimental zoologists, including the students of animal behavior, are most keenly interested in the modifiability of the organism, and their experiments are usually devised for the special purpose of determining the amplitude and peculiarities of this modifiability. The entomologist, however, who is attempting to use parasitic insects as tools or implements in controlling the depredations of other insects, is primarily interested in the stability of structure and constancy of behavior. This follows from the very nature of his work. As the essential excellence of a tool consists in its remaining the same as it was when it left the hands of the manufacturer, so a parasitic species can be used as an efficient tool only if it behaves generation after generation with uniform constancy. Hence in combating pests, only those

gists in our own country during the period characterized by a very exclusive occupation with morphology in our universities: Riley, "Parasitism in Insects," *Proceed. Ent. Soc. Wash.*, II., No. 4, 1893, 35 pp.; Webster, "Insect Parasites," 15 pp. (reprint without date); Osborn, "Insects Affecting Domestic Animals," Bull. No. 5, U. S. Dept. Agric., 1896, 302 pp., 170 figs.; Howard, "A Study in Insect Parasitism," Tech. Ser. No. 5, U. S. Dept. Agric., 1897.

[19] "Das Eindringen von Wurgeln in lebendige Gewebe," *Botan. Zeitg.*, III., 1894, pp. 169–176; "Artificial Parasitism," *Botan. Gazette*, XXXVIII., 1904, pp. 214–217.

[20] "The Conditions of Parasitism in Plants," Carnegie Inst. Publ., Washington, 1910, 60 pp., 10 pls., 2 text-figs.

parasitic insects can be utilized to advantage that are not only prolific and will endure the climatic conditions into which they have been artificially introduced, but will maintain very definite relations only with individuals of a single or of a very few host species and destroy them in their earliest possible ontogenetic stage before they can do extensive damage.[21] Such constancy is especially necessary in primary and tertiary parasites, since whenever these show a tendency to become secondaries and quaternaries, as is sometimes the case, they become harmful instead of beneficial.[22]

It is clear that the determination of the constancy or invariability of parasitic reactions as a basis for practical applications requires, if anything, an even greater insistence on the experimental method than does the determination of the range and character of modifiability for purely theoretical purposes. Ever since the days of Redi both theoretical and practical entomologists have resorted to the experimental method and therefore have no reason to regard themselves as behind the times in appreciation of what some zoologists have been heralding as a recent dispensation. In other respects, however, the students of insect life are "old fashioned" and resemble the botanists more closely than the zoologists, in that they are constrained by the extraordinary intricacy of their science to maintain the closest and most sympathetic cooperation with the taxonomists, morphologists, and students of geographical distribution. Without this cooperation their studies of insect parasitism would resolve themselves into a weltering chaos.

[21] Howard and Fiske (*loc. cit.*, p. 204) express a similar opinion when they say that "it is probably true also that among those parasites which are the most closely restricted in their host relationships are to be found those which are the most effective in bringing about the control of their respective hosts. This is primarily due to the fact that a correlation usually exists between the life and seasonable history of such a parasite and some one or more hosts which it is particularly fitted to attack. The existence of a correlation between parasite and host of such intimate character makes possible the continued existence of the parasite independently of alternate hosts, and it is thus enabled to keep pace with the one species upon which it is peculiarly fitted to prey when other circumstances are favorable to its increase. Some of the most interesting examples of correlation of this sort which have yet come to attention are to be found among the tachinid parasites of the gypsy moth or the brown-tail moth, and on this account as well as on a purely empirical basis they are now considered much more likely to become important enemies of these hosts than before their characteristics were so well understood."

[22] A very instructive case of such instability in hyperparasitism, or rather superparasitism, is seen in *Pteromalus egregius,* which was introduced into Massachusetts as a primary parasite of the brown-tail caterpillar. This European parasite, as Fiske has recently shown (Howard and Fiske, *loc. cit.*, p. 267 *et seq.*) has not only spread over a great area in eastern New England, since it was first liberated in 1906 and 1907, but besides acting as a primary parasite, it may also behave as a secondary, tertiary or quaternary superparasite.

MATHEMATICS AND ENGINEERING IN NATURE

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WHEN up on the heights, among the imposing wilderness of rocks, crags and pines, the mountaineer is struck by the roaring sound of a storm, he may observe clearly that the weather-beaten trees of a mountain forest, like other organic beings, have to defend themselves against the external attacks of nature. In other words, they have to make provisions to grow in spite of precarious circumstances and to resist many violent disturbances. The adaptability of organic beings to surrounding conditions and the existence of special means of resistance against inner and outer enemies are well known biological facts. That nature in its domain of activity, however, also makes extended use of such principles to which the engineer is accustomed in carrying out his projects, seems to be less generally known. In many instances nature is far in advance of the best human efforts in regard to rational construction. To the eye of the attentive observer, nature even may show pictures which in a beautiful manner reveal definite geometric configurations and relations.

It is not surprising that this should be the case, and might be expected. The axioms of geometry are abstract statements of primitive experiences in space. In fact, according to Picard,[1] geometry may be called the theory of space and, as such, has its origin in experience. Geometric configurations as exhibited by nature are therefore necessarily in accord with the results deduced from the geometric premises. Conversely, within the space of our experience the theorems deduced in ordinary geometry are not contradicted by nature. This statement does, of course, not exclude the possibility of other consistent theories of space, as, for instance, established in the so-called non-Euclidean geometries. The tremendous advantage of the ordinary, or Euclidean geometry, lies in the relative simplicity and adequacy of its application to physical space. As Painlevé[2] states, the science of mechanics, in the philosophical aspect of its foundations, does not differ from that of geometry. Its axioms also are derived from primitive experiences. No science can be created by purely formalistic logic.

Returning to the innumerable objects of natural growth, I shall confine myself to a description of the architectural and mechanical features of a few most conspicuous examples.

The contour-lines of a column or tower, all of whose horizontal

[1] "De la méthode dans les sciences," pp. 1–30, Paris, 1909.

[2] "De la méthode dans les sciences," pp. 336–407.

cross-sections are subject to constant specific stresses, are geometrically defined by cubic parabolas. This form results from the law of stresses under the given conditions, and may be seen in the contour of heavily supporting bridge piers, the Eiffel tower in Paris and numerous other structures. Precisely the same problem nature has solved in building the trunks of tall trees. The famous coniferous trees of California (Fig. 1) offer the best illustration for this principle. The reason for this lies in the fact that the maximum strength of the material used in one and the same engineering structure, or in a tree, being a known constant, it is evidently of the greatest economic advantage to make the specific stresses throughout as uniform as possible.

Fig. 1.

To resist great lateral bending forces, or moments caused by strong and irregular winds, the large trees of the forest are equipped with powerful wind-struts near the base and extending to the anchoring roots (Figs. 2 and 3). The same thing the architect does when he provides for buttresses in Gothic buildings, or when he reinforces the base of a column to secure lateral stability. The more the trees are exposed to the winds, the larger the crown, the more the principle of buttresses and pillars assumes its functions. Wherever winds from a certain direction prevail, one notices plainly that in such a region the wind-struts of the trees on the side opposite to the attack of the wind are most strongly developed. In mountainous regions where on account of the rough character of the surface, the winds are very turbulent and are making their attacks in violent gusts from all directions, one may observe wonderful and grotesque shapes of root-stocks. In a seemingly almost impossible manner the roots crawl over each other, over rocks and around irregular cliffs, simply to find in a crack some ground for anchorage (Fig. 3).

From a technical standpoint also the cell structure of trees and other plants must be considered as a wonderful manifestation of the resources of nature.[3]

Fig. 2.

In this respect, the stalk of a rye-plant may be mentioned as a typical example. This plant meets the same requirements that are

[3] Schwender, ''Mechanische Probleme der Botanik,'' Leipzig, 1909.

necessary in the construction of a high tower. The base of the whole structure is subject to the pressure of the entire load above, and must be able to resist it by compressive strength. Horizontally inserted beams, carrying loads, must have strength to resist bending. There are, furthermore, forces of gravity and all kinds of strains, caused by shearing and torsional forces, which must be accounted for. Considering the fact that in the growth of a rye-plant nature provides completely for the resistance against this complicated system of stresses, and com-

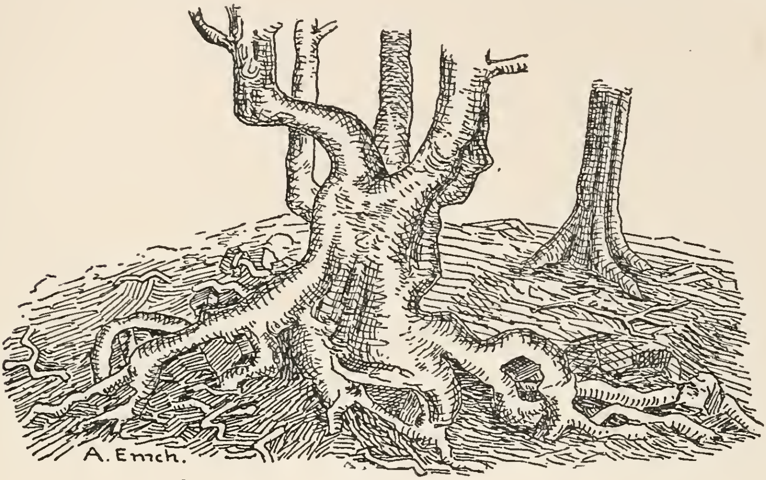


FIG. 3.

paring this kind of engineering with corresponding human efforts, then even the famous and much admired Eiffel tower appears as a relatively large and clumsy structure.

According to Francé,[4] a rye stalk has an average height of 1,500 millimeters and a diameter of 3 mm. at the base. This, transformed to the proportions of architecture, means that nature has here established a structure which in comparison is 33 times the height of one of the towers of the Cathedral of Cologne. Imagine now that at the top of such a colossal tower a proportionally large and heavy ear of rye be pendling, and we get an idea of the amount of compressive, tensile and bending strength a plant-stalk may acquire. We become aware that the plant, with extreme perfection, applies the same principles with which the engineer is working. One discovers relations which the engineer finds in studying moments of inertia, bending moments, etc., in beams, girders, columns, and all kinds of trusses. Thus the plant produces extremely complex structural phenomena, which, from the standpoint of the engineer, reveal a masterful knowledge of the laws of mechanics and the consequent economy of materials. The same statement applies to the physiological problems of zoology.

[4] "Illustrierte Zeitung," 1909.

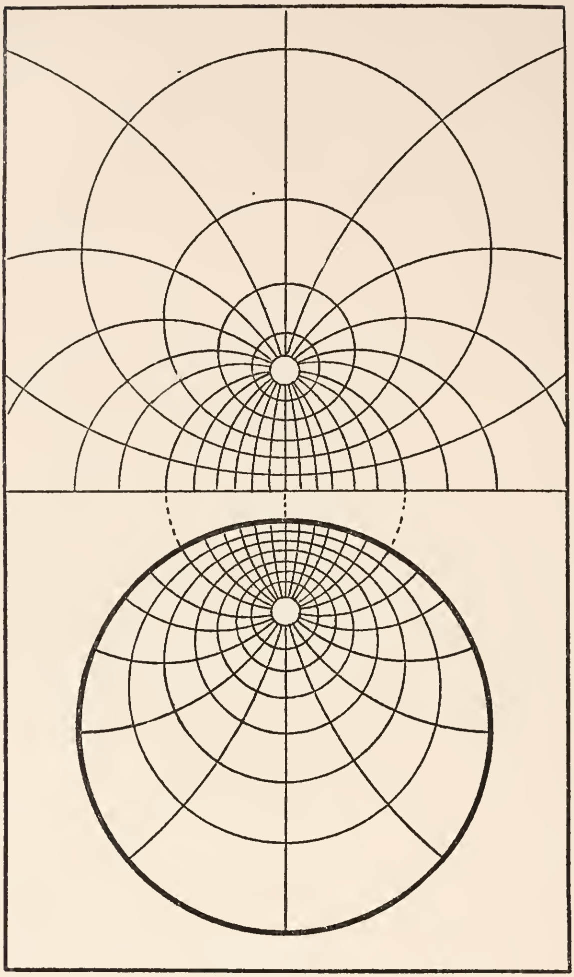


Fig. 4.

While in the foregoing examples special stress was put on the relative identity of mechanical principles in engineering and nature, it will, in the next place, be interesting to show that in many cases the laws of rational construction and design are at a glance geometrically apparent.

If we think of the cross-section of a tree, further growth must necessarily occur in directions normal to the surface of the last year-ring. This causes the year-rings and pith-rays to form a system of orthogonal trajectories. In Fig. 4 such a system, consisting of two conjugate pencils of circles, is shown, and is caused by a rate of growth greater in one direction than another.

The inner yellow portion of a daisy (*Chrysanthemum leucanthemum*) exhibits a beautiful geometrical arrangement of its elements. By the mathematical principle of conformal transformations it can easily be proved that the best distribution of the elements is obtained when the lines appearing in the configuration of the flower (Fig. 5) are logarithmic spirals.[5]

In a similar manner the location of the leaves along the stem of a plant is determined by remarkable numerical relations.[6] The fraction n/m expressing the parts of the circumference by which consecutive leaves are separated are constant for each species and are the successive approximations of the continued fraction

$$\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cdots}}},$$

i. e., $1, \frac{1}{2}, \frac{2}{3}, \frac{3}{5}, \frac{5}{8}, \frac{8}{12}, \cdots$, which, on the other hand, are also the terms of a special Lamé's series. Arranging the leaves according to these fractions, nature insures for each species the best distribution of light and masses, and consequently the best growth.

Helical motion in the growth of certain plants around supporting poles may be explained mechanically. The outer parts exposed to the light grow faster than the inner portions, with the resulting tendency to bend the stem around the pole. This, combined with the upward growth, produces the spiral motion. The fact that most climbing plants, with a few exceptions (hops, *Polygonum convulvulus*, etc.), show left-handed twisting may be circumscribed by calling it "geo-

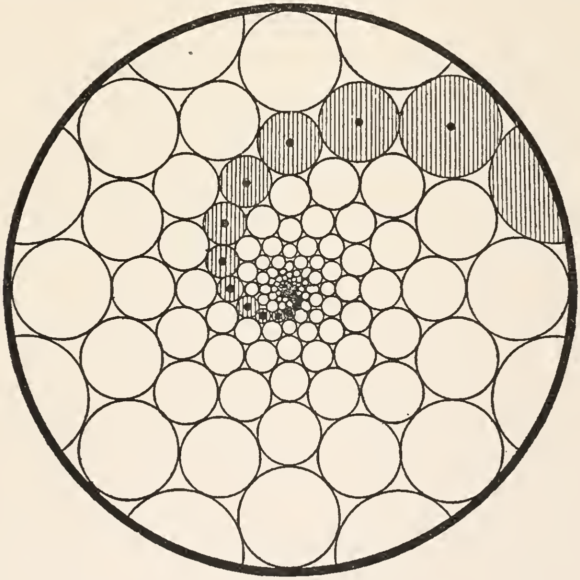
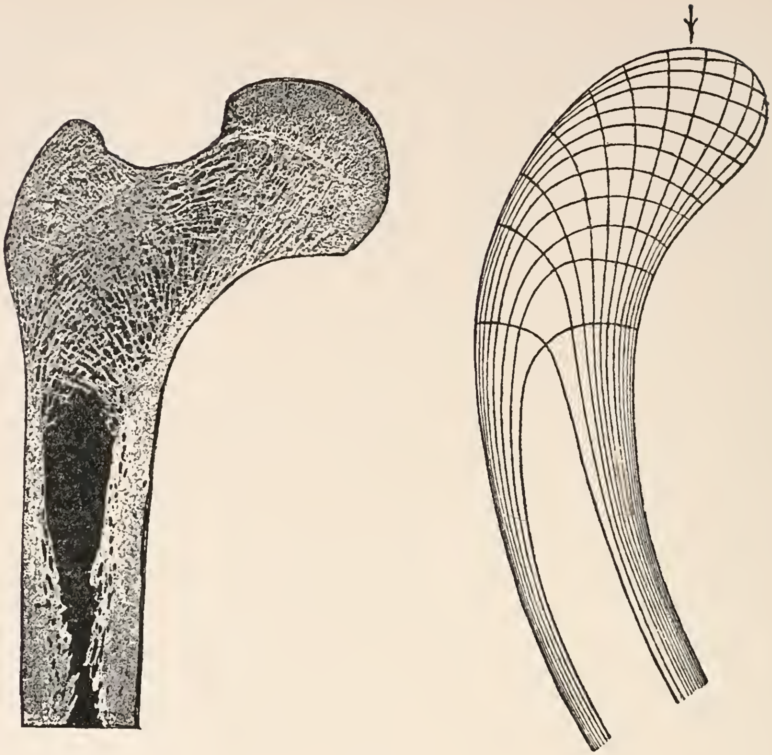


Fig. 5.

[5] Emch, "L'Enseignement Mathématique," Vol. 7, p. 722 (1910).

[6] Strassburger, "Lehrbuch der Botanik für Hochschulen," pp. 31–35.



a FIG. 6. *b*

tropism." This, however, does not give a mechanical reason for it; not more so than for the left-handed spirals of snail-shells. In the Rocky Mountains I have often noticed this peculiar tendency in the uniform twisting of the fibers of the Lodge Pole pine.

The plain appearance of geometric configurations and relations is, of course, not limited to plant life alone; mineralogy, zoology and geology also offer many examples of this kind.

The forms of crystals, for instance, may be derived abstractly from certain considerations in the theory of groups.

Mendel's law of heredity has in recent years become of extreme importance as a powerful means of research.[7] The abstract form of this law is derived from combinatory analysis, as will appear from the following experiment of L. Cuénot.[8] All individuals of the offspring resulting from the crossing of the ordinary gray mouse with the albino mouse are gray; the gray element G dominates, while the white element W is hidden by the gray. Crossing individuals of the offspring, among the new offspring there will be gray and white specimens, and the ratio

[7] Lang, "Uber die Mendelschen Gesetze, etc.," *Schweiz. Naturf. Gesellsch.*, Luzern, 1905.

[8] *Revue Scientifique*, Paris, 1906.

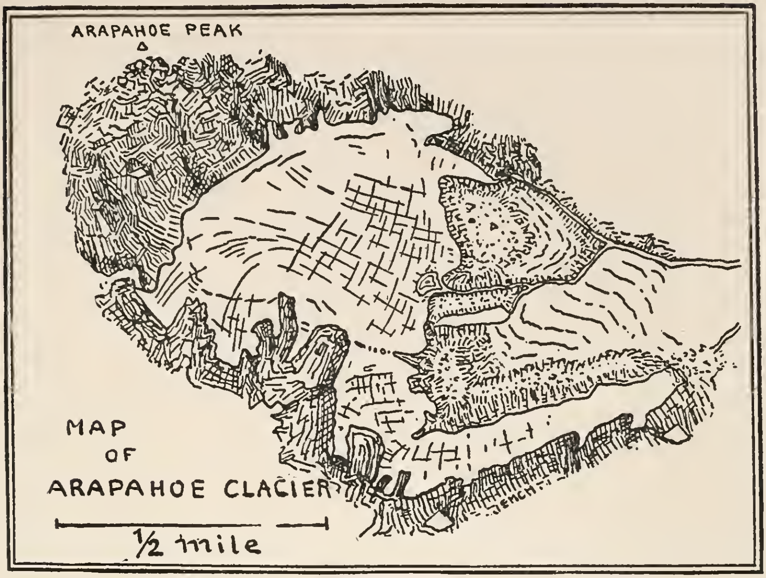


Fig. 7.

of their respective numbers is generally 3 to 1. To explain this fact, first observed by Mendel, the hypothesis is made that in crossing the specific sexual elements merely associate and do not form a new uniform individual element. Among the *G*- and *W*-elements, in equal numbers, the following combinations are possible during the act of generation:

G and *G*,
G and *W*,
W and *G*,
W and *W*.

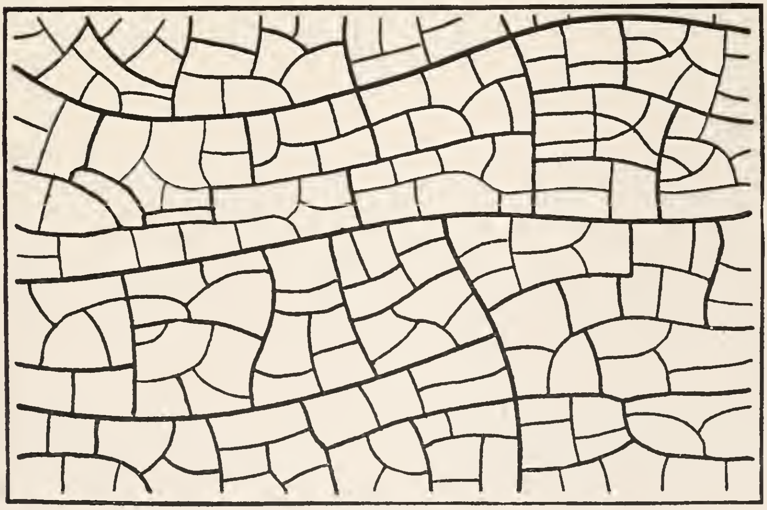


Fig. 8.

Each of these combinations is the starting point for a new individual. It will be gray if there is a dominant G in the combination. Hence, among the offspring there will be three gray and one white. The result may be expressed by the formula

$$GW \cdot GW = 1GG + 2GW + 1WW,$$

which is corroborated by similar experiments of other investigators.

In graphic statics, one of the most valuable branches of structural engineering, may be found the reason for the peculiar distribution of the substance in the upper portion of a thigh-bone along orthogonal trajectories (Fig. 6 *a*). This is in analogy with the problem of a crane-like structure, as diagrammatically shown in Fig. 6 *b*. It is well known that the curves of maximum compression and tension in a strained body form an orthogonal system,[9] and it seems natural that in order to insure greatest strength, cell matter should be deposited according to this system.

An orthogonal system formed by the stream lines and lines of greatest tension, which appear as lateral cracks and crevasses, is shown in most glacial movements (Fig. 7). The directions of corresponding stresses and sections upon which they act form an involutoric pencil of rays. The case where the field is exclusively subject to tensions only leads to elliptic involutions around all points. Every involutoric pencil admits of a rectangular pair, corresponding to the maximum and minimum stresses; tensions in this case. The effect of this condition is shown in Fig. 8, representing the cracks of a mud-bed or on a heavily varnished surface which is drying up. In this case only tensile normal stresses act on the rectangular pair. One is a maximum, the other a minimum. After a crack has formed, the maximal stress and strain normal to the crack has been relieved, so that the former minimal normal tension along the crack becomes now the maximum. The next rupture will therefore be orthogonal to the first crack. The reason for this peculiar configuration is thus found by the methods of projective geometry.[10]

A great number of other examples from the realms of natural history might be added which all would give further evidence of the fact, that the whole evolution of the inventive and creative human intellect is reflected by the well-perceived phenomena of nature.

By the laws of the universe the human mind is forced to repeat the same logic conclusions, according to which the rest of the organic world and nature in general manifest themselves.

[9] Ritter, "Graphische Statik," Vol. 1, pp. 128–134.

[10] Emch, "An Introduction to Projective Geometry and its Applications," pp. 239–241, New York, 1905.

AMERICAN MATHEMATICS

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ABOUT a dozen years ago a well-known French mathematician wrote as follows in reference to our mathematical situation:[1] "Mathematics in all its forms and in all its parts is taught in numerous [American] universities, treated in a multitude of publications, and cultivated by scholars who are in no respect inferior to their fellow mathematicians of Europe. It is no longer an object of import from the old world but it has become an essential article of national production, and this production increases each day both in importance and in quantity."

Taken by itself this assertion looks good and it is doubtless more nearly true to-day than it was at the time of publication. If we turn our eyes away from this statement and rest them upon the mathematical book shelves of a good library, we can not fail to notice that our accomplishments do not seem to be in accord with the complimentary statement noted above. This disaccord will become still more evident if we look through the pages of some of the standard works of reference, such as the great mathematical encyclopedias which are now in the course of publication.

If a student of the history of mathematics would make a list of the leading mathematicians of the world during the last two or three centuries, arranging the names in order of eminence, he would have a fairly long list before reaching the name of an American. Such names as those of Euler, Cauchy, Gauss, Lagrange, Galois, Abel and Cayley have no equals in the history of American mathematics; and, among living mathematicians, probably all students would agree that there are no American names which should be placed on a mathematical equality with those of Poincaré, Klein, Hilbert, Frobenius, Jordan, Picard and Darboux. Both of these lists of names could be considerably extended without any danger of being unfair to the mathematicians of this country, but they suffice to establish the fact that our mathematical situation is not yet satisfactory, notwithstanding our remarkable progress during recent decades.

This unsatisfactory situation is reflected in many of our standard books of reference. For instance, under such an important word as "matrix" one finds in Webster's New International Dictionary (1910)

[1] Laisant, "La Mathematique, Philosophie-enseignement," 1898, p. 143.

the following statement: "The matrix has also significance apart from its development into a determinant." In view of the fact that a matrix, as commonly used by mathematicians, has no possible development, it is clear that the given sentence does not convey any information. In fact, the other remarks under this term are almost equally objectionable, and they raise the question whether a philosopher should be selected to define the mathematical terms of a standard work.

It is not implied that such an extensive work as a large dictionary could be expected to be free from defects, but there is always a limit to the number and the type of those which appear excusable. When one reads in such a dictionary that "algebra is that branch of mathematics which treats the relations and properties of quantity by means of letters and symbols," and then turns to page 22 of volume 1 of the large French mathematical encyclopedia and reads that "it is convenient, in arithmetic, to represent any number by a letter, it being understood that this letter denotes a single and the same number whenever one remains in the same subject," it becomes evident that the given definition of algebra is not supported by some of the highest authorities.

In fact, such terms as arithmetic, algebra and geometry are used with such a wide range of meanings by eminent authorities that it seems impossible to give satisfactory definitions of them, and our dictionaries would convey more reliable information about mathematical terms by stating this fact, together with some indication of what broad subjects are generally classed under these terms, than by giving categorical definitions which can be accepted only by those who have a meager knowledge of mathematics.

Without implying that Webster's New International Dictionary is any less reliable with respect to mathematical matters than most others, we shall refer to one more instance of misleading statements in this work. On page 2547 we read as follows: "The cipher was originally a dot, used as a mere arbitrary sign to mark place or local value." Such a definite statement seems strange in view of the fact that the origin of zero is one of the unsettled questions of the history of mathematics. It is of interest to note in this connection that Cantor changed his view with respect to the origin of this concept and this symbol, in the third edition of Volume I. of his classic "Vorlesungen ueber Geschichte der Mathematik," where he states that the symbol for zero and the positional arithmetic are probably due to the Babylonians instead of to the Hindus, as he had stated in the earlier editions of this work, and as is stated in a large number of other works.

Our encyclopedias also frequently exhibit careless editing along the line of mathematical terms, and the choice of editors for such work often seems to indicate that the general editor regarded the choice of the mathematical editors as a matter of little consequence. Possibly those who would be best qualified to render excellent service along this line are unwilling to undertake it in view of the large amount of labor which it involves.

As an instance of a decided misstatement in one of the best of these encyclopedias we may cite the following: "Sylow (1872) was the first to treat the subject [substitutions] apart from its applications to equations."[2] Very little reading along the line of the development of the theory of substitutions would reveal the absurdity of this statement. Nearly all of Cauchy's fundamental work along the line of substitutions was no more intimately connected with the theory of equations than the articles by Sylow. Similar remarks apply to most of that part of Jordan's work which antedates Sylow's fundamental article, and also to the work of a number of other authors.

Judging from the following words of Sir Oliver Lodge; "the mathematical ignorance of the average educated person has always been complete and shameless,"[3] one could not expect to find very much better conditions in England. In fact, in consulting the large Murray English Dictionary, published at Oxford, England, the writer found under the first mathematical term which he consulted, viz., the word "group," not only an incomplete definition, but also the following incorrect statement: "The idea of group as applied to permutations or substitutions is due to Galois." As a matter of fact, the idea of permutation groups was clearly developed by Ruffini about thirty years before Galois, not to mention the still earlier work by Lagrange and the early publications of Cauchy and Abel.

One of the most direct inferences from what precedes is the fact that there is too much mathematical indifference. If more vigorous protests against the inaccuracies in our standard books of reference would be made, publishers and general editors would doubtless exercise greater caution in the selection of their mathematical editors. This mathematical indifference is perhaps still more disastrous when it exists among university administrators. Judging from several of the recent appointments in leading universities, it would appear that we are not moving as rapidly towards high mathematical ideals as one might wish.

The English-speaking pure mathematicians constitute more nearly a terra incognita than the workers in any other large field of knowledge. This is partly due to the nature of the subject and partly to the fact that there are so few mathematical works of reference in the English language. There never has been a good mathematical encyclopedia or other work of general reference in this language, while the French and Germans have had several such works in addition to the great encyclopedias which are now in the process of publication. All large mathematical histories have appeared in foreign languages.

[2] New International Encyclopedia (1904), under "Substitutions."

[3] "Easy Mathematics," 1906, preface.

As a result of this lack of intermediate mathematical literature comparatively few of our people know what constitutes a mathematician of high order. The time has been when even the educated public seemed to believe that the author of a successful series of elementary text-books had necessarily gained a place among the great mathematicians of the world. As several of our most popular recent series of text-books were edited by men of remarkably low mathematical attainments, this view is no longer so generally held, but it is questionable whether it has been replaced by a more correct one on the part of the majority of those who feel entitled to express an opinion on the work of mathematicians.

In looking over the work of the fourteen great mathematicians mentioned above one finds that all of them published mathematical articles and that a majority of them also published treatises. Two of them, Abel and Galois, died at an early age, before they had time to develop sufficiently the fields in which they were interested to write extensive treatises. This is especially true of Galois, who published only five papers during his short lifetime of only twenty years, but several of his other papers appeared later.

The extent of the publications of the mathematicians mentioned above varies from the comparatively few brief articles by Galois to the voluminous publications by Euler, which are just now appearing in a collected form and are expected to fill forty large volumes. Judging from the great mathematicians of the recent past, it would appear that publication of original articles is one essential of greatness, but greatness is not measured so much by the number and the extent of such publications as by their merits. It should, however, be observed that nearly all of the great mathematicians of the recent past have published a large number of research papers. In the case of Cayley, who is the only Englishman in the given lists, the number of these papers is about one thousand.

America has never had a mathematician who published as extensively as some of the European mathematicians, and the average extent of our publications is much below the average of the leading mathematical countries of Europe, if we exclude the elementary text-books. It is doubtless true that the most important consideration at present is the improvement of the quality of our publications, but we are also in need of more mathematical journals to insure more rapid publication of good research material. If the crowded condition of our research journals would induce a larger number to assist in bringing out more good intermediate mathematical literature, it would doubtless be of great importance for the future advancement of the science.

One of the leading agencies in bringing about rapid mathematical advances during the last few decades is the American Mathematical

Society, which is now one of the strongest mathematical societies of the world and has probably a larger income than any other similar organization. It publishes two journals and its frequent meetings furnish favorable opportunities to renew zeal and to cooperate in the more important advances. These meetings serve also as a good medium to spread reliable information in reference to young men of promise and to secure for them more prompt recognition than would otherwise be possible.

One of the most hopeful signs as regards American mathematics is the fact that our students are in close contact with several of the mathematical centers of Europe. It is no longer true that nearly all Americans who go abroad for the purpose of studying mathematics locate in the same institution or in the same country. In recent years, Italy has grown rapidly in favor, while the leading universities of Germany and France continue to attract a considerable number of our best students. The rapid interchange of ideas resulting from the scattering of our mathematical students in foreign countries is doing much to dispel prejudices, to make American mathematics cosmopolitan, and to awaken a keener appreciation of the advantages and the disadvantages of our own institutions.

If one bears in mind the facts that our library facilities were very poor until recent years and that no locality offers in itself any special inducements for mathematical study, one should perhaps be surprised by the rapid mathematical advances during the last few decades rather than by the fact that we have not yet attained to greater national eminence. It remains to be seen whether we shall ever be on an equality with the leading mathematical nations of the world. The rapidity with which we have obtained respectful recognition and the American eminence in some of the other sciences might reasonably awaken the hope that we may be not far from the time when we shall deserve, in the strictest sense, the position pictured in the first paragraph in such a friendly spirit.

BUFFON AND THE PROBLEM OF SPECIES

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I

THERE is no chapter of the history of the theory of organic evolution more confused or more controverted than that which relates to the position of Buffon. Upon one point, indeed, nearly all expositors of the "Histoire Naturelle" are agreed—namely, that Buffon's own expressions on the subject, if taken at their face value, contradict one another. But upon the questions whether his utterances were meant to be taken at their face value; whether, by a due consideration of dates, the contradictions can not be regarded as consecutive steps in a logical progress of doctrine; whether he was in the main a partisan or an opponent of transformism: upon these questions both the biographers of Buffon and the historians of evolutionism are greatly at variance.

The rival interpretations fall into six groups: (1) Older writers of the anti-evolutionary school, such as Cuvier and Flourens, while admitting that (in the words of Flourens) "the ideas of Buffon were constantly subject to profound mutations," were wont to maintain that in the last analysis and in the long run he must be counted among the defenders of the doctrine of immutability of species. Among recent writers Packard gives a similar account; while he recognizes "tentative" evolutionistic utterances in the "Histoire Naturelle," he opines that Buffon himself "did not always take them seriously, but rather jotted them down as passing thoughts." (2) One of the earlier French evolutionists, Isidore Geoffroy St. Hilaire,[1] contended that there was no mere fluctuation in Buffon's teaching, but simply an orderly movement of thought from one position to another.

> Buffon does but correct himself; he does not fluctuate. He goes forward once for all from one opinion to another, from what at the outset he accepted on the authority of another to what he recognized as true after twenty years of research.

The successive phases of opinion through which, according to Isidore Geoffroy, Buffon passed were three. At the beginning of his work (1749) and down to 1756 or later, he "still shared the views of Linnæus" and affirmed consistently the theory of immutability. From 1761 to 1766 he asserted the hypothesis of variability in an extreme form. Later he became convinced that "in setting himself free from the prevailing notions," he had, "like all other innovators, gone some-

[1] In his "Histoire Naturelle Générale," Vol. II., 1859. His account is translated in Butler's "Evolution Old and New."

what to the opposite extreme"; and in all his writings subsequent to 1766 he held to a doctrine of "limited mutability," to the "permanence of the essential features" of species and "the variability of details." This division of Buffon's opinions into three periods, of which the middle one was characterized by an extreme evolutionism, has been accepted by a number of later writers. It is apparently adopted by Osborn, though not to the exclusion of other interpretations inconsistent with it.[2] (3) By several recent writers—such as Samuel Butler, de Lanessan, Giard, Clodd—Geoffroy's scheme of three periods is rejected, and Buffon is declared to have been an evolutionist throughout virtually his whole career as a writer. Those who take this view explain away his apparent self-contradictions by various suppositions. Giard, for example, holds that Buffon began as a transformist, but was led by his difficulties with the ecclesiastical authorities (in 1751) to conceal his real position for a number of years, becoming bolder and more outspoken after 1761, when his fame was securely established. In other words, Giard proposes an alternative division into three periods, in which the middle phase is the *least* evolutionistic. Samuel Butler, who has taken the most extreme ground of all in favor of the view that Buffon was a whole-hearted evolutionist, endeavors at great length and with much ingenuity to show[3] that all the anti-evolutionary passages in the "Histoire Naturelle" are ironical. According to this interpretation Buffon must almost be said to have woven a sort of cryptogram into his work. "His irony is not the ill-natured irony of one who is merely amusing himself at other people's expense, but the serious and legitimate irony of one who must either limit the circle of those to whom he appeals, or must know how to make the same language appeal differently to the different capacities of his readers, and who trusts to the good sense of the discerning to understand the difficulty of his position, and make due allowance for it." In other words, Buffon threw in sufficiently frequent affirmations of the immutability of species to deceive, or at least to quiet, the doctors of the Sorbonne, and in the very act of doing so he made it evident to the judicious reader that the opposite conclusion was the one to be accepted.

The three remaining interpretations of Buffon's position are less subtle and ingenious. (4) The author of the most comprehensive recent history of biological theories[4] tells us that, though Buffon "speculated about the origination of one species from another," he did not "especially interest himself in the question of the mutability of species; his too little developed sense for the historical [*i. e.*, the genetic] aspect of nature did not permit him to put clearly before himself such a question as that concerning the origin of species. How should he have done so, since he did not even believe in the existence of species, but recog-

[2] "From the Greeks to Darwin," 130–135.

[3] In his "Evolution Old and New."

[4] Rádl, "Gesch. der biologischen Theorien," I., 1905, pp. 117–118.

nized only individuals?" (5) Dacqué, in what is at many points the least inaccurate of the histories of evolutionism,[5] declares that Buffon brought forward no more profound ideas than his contemporaries "upon the interconnection of the phenomena of organic nature," though he did something to clarify the conception of geological evolution, and "regarded species as variable within certain limits." (6) The writer who (so far as I know) has most recently discussed the subject, Landrieu,[6] seems finally to give up as hopeless the attempt to reduce Buffon's utterances to harmony and coherency. He adds, however, that in spite of these inconsistencies, "Buffon retains the indisputable honor of having been the first zoologist to admit the possibility of specific variations due to environmental influences and extending beyond the limits of species."

All of these accounts of the matter seem to me to be either inadequate or erroneous, though all may be said in some measure to be founded on fact. Most of them—especially of the more recent ones—wholly ignore two essential considerations in relation to Buffon's biological conceptions, in the light of which all that he wrote must be interpreted. In attempting to present a more adequate and more correct analysis of Buffon's opinions, I shall be obliged to tax the reader's patience with many and lengthy citations. Where there has been so much disagreement, it is necessary to present the proofs for nearly every statement propounded. And where so much error has arisen through the citation of brief passages in disregard of their contexts, it is important that pains be taken to quote or summarize so much of each text as appears to be in any way relevant to the question under consideration.

1. The first volume of the great treatise (1749) opened with a preliminary disquisition on the methodology of the science, a "Discours de la manière d'étudier et de traiter l'histoire naturelle." In this Buffon gave a salutary emphasis to the demand for a more "philosophical" way of studying botany and zoology than had been exemplified by Linnæus and Tournefort and the other great systematists. Description and classification, Buffon insisted, were the least part, though a necessary part, of "natural history."

We ought to try to rise to something greater and still more worthy of occupying us—that is to say, to *combine* observations, to generalize the facts,

[5] "Der Descendenzgedanke u. seine Geschichte," 1903—a little book less known than it deserves to be.

[6] In his "Lamarck, fondateur de l'évolution," 1909, pp. 275–283. May I improve this occasion to express the hope that both French and English writers may some day be broken of the habit of talking of "evolution" when they mean "evolutionism"? Both languages chance to be provided with a suffix for distinguishing a theory which affirms, or relates to, a given fact from the fact itself; it seems a pity to throw away this instrument of linguistic precision. It is surely absurd (not to say profane) to speak of Lamarck or any other mortal as "the founder of evolution"; or of the eighteenth century as "the beginning of evolution."

to link them together by the force of analogy, and to endeavor to attain that high degree of knowledge in which particular effects are recognized as dependent upon more general effects, nature is compared with herself in her larger processes, and thus ways are opened before us by which the different parts of physical science may be perfected. For success in the former sort of study there are needful only a good memory, assiduity and careful attention; but for the sort of which we are here speaking other qualities are requisite: breadth of view, steadiness of vision, a power of reasoning formed by the practise of reflection even more than by learning. For such study, in short, a man must have that quality of mind which enables him grasp remote relations between things, to bring them together, and thereby to form a body of reasoned conclusions, after having duly estimated similarities and weighed probabilities.

But these judicious and stimulating, if slightly vague, appeals for the conversion of natural history into a science of causal relations and generalized laws, were not the principal purpose of the preliminary discourse. The thought of Buffon at the time when he wrote that essay seems to have been dominated above all by a single idea, which was also one of the two or three ruling ideas of the whole of the first half of the eighteenth century—namely, the Leibnitian "principle of continuity" (*lex continui*). In the intellectual fashions of this period, next to the blessed word "Nature" the most sacred phrase was "the Great Chain of Beings"; indeed, one of the truths that man was supposed to know most surely about nature was that she "makes no leaps." In the form, especially, of the neo-Platonic and Spinozistic metaphysical assumption that all possible forms must exist, the principle was much older than the philosophy of Leibniz;[7] but it owed to him and his disciples a more definite formulation and a greatly increased popular currency. It declared that all entities are arranged in a graded scale of similarity, so that for every being that exists there also exists some other (in the strict version of the principle, one and only one other) from which its difference is infinitesimal, *i. e.*, less than any assignable difference. A typical statement of the doctrine is Bonnet's:[8]

Between the lowest and the highest degree of corporeal or spiritual perfection there is an almost infinite number of intermediate degrees. The series of these degrees constitutes the *Universal Chain*. It unites all beings, binds together all worlds, embraces all spheres. One Being alone is outside of this chain, and that is He who made it. . . . There are no breaks (*sauts*) in nature; all is graduated, everything shades off into the next thing. If, between any two beings whatever, there existed a gap, what would be the reason of the transition from the one to the other? There is, therefore, no being above or below which there is not some other that approximates it with respect to some characters and diverges from it with respect to others.

All this (as Bonnet's language intimates) was held by the Leibnitian philosophy to be logically implied by the still more fundamental "principle of sufficient reason." For if the gradations found in nature

[7] This implied that there must be one, and can be only one, sample of every possible kind or degree of entity. To consider Leibniz's attitude toward this form of the principle would involve too much technical metaphysics.

[8] "Contemplation de la Nature" (1764), 2d ed., 1769, I., 26–27.

were discontinuous, if between any two beings an intermediate type were logically capable of existing, but actually non-existent, the universe would stand convicted of irrationality. A thing for the existence of which there was just as much "reason" as there was for the existence of certain other things would have failed of realization, while the others arbitrarily enjoyed the privilege of actuality. The principle of continuity owed its vogue in part, also, to the influence of the Leibnitian calculus, which had brought infinitesimals and the notion of the continuum peculiarly into fashion.

Applied primarily to the "monads" of Leibniz's metaphysics, the principle found a multitude of other applications. It served, for example, as the chief basis of the arguments for optimism of which the early eighteenth century was so fond. Pope's "Essay on Man" is full of the argument from the necessity of continuity to the necessity of imperfections and apparent evils.

> Vast chain of being! which from God began;
> Nature's ethereal, human, angel, man,
> Beast, bird, fish, insect, whom no eye can see,
> No glass can reach; from infinite to thee,
> From thee to nothing. On superior powers
> Were we to press, inferior might on ours;
> Or in the full creation leave a void,
> Where, one step broken, the great scale's destroyed.

For the limitations of man's lot the sufficient consolation is that the principle of continuity requires them; in a system

> Where all must full or not coherent be,
> And all that rises, rise in due degree,—
> Then in the scale of reasoning life 'tis plain
> There must be, somewhere, such a rank as man.

From the assumption of the same principle sprang the inquiries from which the science of anthropology may be said eventually to have originated. As a historian of the beginnings of that science has said:

> The question concerning the line of demarcation between man and the animal kingdom was plainly forced upon anthropology by the philosophy of Leibniz. The *lex continui* demanded the discovery of that "grade" (*nuance*) of existence among the higher organisms which comes nearest to the human species. And so there began the celebrated quest of the "missing link." In the first phase of this quest, the missing link was sought at the lower limits of humanity itself. It was held to be not impossible that among some of the more remote peoples semi-human beings might be found, such as had now and then been described in travelers' tales. Some voyagers had testified to having seen with their own eyes men with tails; others had encountered tribes incapable of speech. Linnæus mentions a *homo troglodytes* concerning whom it was not established with certainty whether he was more nearly related to the pygmies or to the orang-outang. The most eminent men of science down to a late period in the eighteenth century hesitated to reject absolutely the possibility of the existence of such beings.[9]

[9] Günther, "Die Wissenschaft vom Menschen im 18ten Jahrhundert," p. 30.

It was, then, the application of this principle to natural history that was Buffon's main object in his preliminary discourse. The consequences of it, when it was applied in this field, were simple and evident and drastic: there can be no such thing as a "natural," or even a consistent "system" of classification, since there are no sharp-cut differences in nature, and since, therefore, species and genera are not real entities but only figments of the imagination. It is easy, Buffon wrote, to see the essential fault in the work of the systematists, the inventors of "methods" as a class.

It consists in an error in metaphysics in the very principle underlying these methods. This error is due to a failure to apprehend nature's processes, which take place always by gradations (*nuances*), and to the desire to judge of a whole by one of its parts.[10]

Man, placing himself at the head of all created things and then observing one after another all the objects composing the universe,

will see with astonishment that it is possible to descend by almost insensible degrees from the most perfect creature to the most formless matter; . . . he will recognize that these imperceptible shadings are the great work of nature; he will find them—these gradations—not only in the magnitudes and the forms, but also in the movements, in the generations and the successions, of every species.[11] If the meaning of this idea be fully apprehended, it will be clearly seen that it is impossible to draw up a general system, a perfect method, for natural history. . . . For in order to make a system or arrangement, everything must be included, and the whole must be divided into different classes, these classes into genera, and the genera into species—and all this according to an order in which there must necessarily be something arbitrary. But nature proceeds by unknown gradations, and consequently can not wholly lend herself to these divisions—passing, as she does, from one species to another species, and often from one genus to another genus, by imperceptible shadings; so that there will be found a great number of intermediate species and of objects belonging half in one class and half in another. Objects of this sort, to which it is impossible to assign a place, necessarily render vain the attempt at a universal system.[12]

In short, the whole notion of species is inconsistent with the conception of nature as a graded continuum of forms in which there are no breaks.

In general, the more one increases the number of one's divisions, in the case of natural products, the nearer one comes to the truth; since in reality individuals alone exist in nature, while genera, orders, classes, exist only in our imagination.[13]

The vogue of the principle of continuity in the eighteenth century

[10] ''Hist. Nat., Vol. I., 1749, p. 20.

[11] These words are Buffon's nearest approach in the introductory discourse to a suggestion of the mutability of species. De Lanessan has interpreted them as an affirmation of transformism; but they are too vague to justify such a construction.

[12] ''Hist. Nat.,'' Vol. I., 1749, p. 13. Much the same thing had, however, been said by Ray over sixty years before; cf. ''Historia Plantarum,'' 1686, I., p. 50.

[13] *Op. cit.*, p. 38.

was, unquestionably, an important influence tending to prepare men's minds for the acceptance of the conception of evolution; but the two doctrines were by no means synonymous, nor did the adoption of the former necessarily imply adherence to the latter. The *lex continui* is historically important because it led to one of the early notable departures in modern thought from what may be called a Platonistic habit of mind, that had, in a hundred subtle ways, dominated most European philosophy and science for many centuries; it meant, in some degree, the abandonment of the fashion of thinking of the universe as tied up in neat and orderly parcels, the rejection of rigid categories and absolute antitheses, as inadequate instruments for the description of the complexity and fluidity and individuatedness of things. In other words, the principle of continuity, though itself the product of the extreme of philosophical rationalism, tended in a mild way towards a sort of anti-rationalism, towards a distrust of over-sharp distinctions and over-simple conceptions, towards a sense of certain incommensurability between the richness of reality and the methods of conceptual thought. And in the nineteenth century this same tendency, in vastly more extreme forms, has been far more conspicuously furthered by the influence of the doctrine of evolution. But the idea of continuity as generally held in the time of Buffon had no reference to temporal sequences and by no means involved, in the minds of those who accepted it, any definite belief in the descent of what are commonly called species from other species.[14] If the presupposition of continuous gradations and imperceptible transitions had been explicitly brought to bear upon genetic problems in biology, it would naturally though not necessarily have suggested some sort of theory of descent. But, curious as the fact may appear, the presupposition was ordinarily not brought into connection with genetic problems at all; it was taken in an essentially static sense.

And it seems to have been taken in this sense by Buffon in the introductory discourse in his first volume. A single obscure phrase, which I have already quoted, might be regarded as hinting at the conception of organic evolution, if the general tenor of the essay lent any confirmation to such an interpretation. But nowhere else in this writing is it even remotely suggested that the conception of the continuity of forms involves the conception of the descent of so-called species from one another. It is scarcely conceivable that if Buffon

[14] This fact has often been overlooked by interpreters of eighteenth century writers. When we find such a writer saying that "nature passes from one species to another by gradual and almost imperceptible transitions," it is by no means safe to assume that the phrase contains any reference to genealogical transitions, or that the writer meant by his words to affirm the transformation of species through the summation of slight individual variations. Misapprehension upon this point has caused some eighteenth century authors to be quite undeservedly set down as evolutionists.

had had before his mind so momentous a new idea as that of evolution, he should not have contrived to give a far plainer intimation of it than a single vague remark that imperceptible gradations are found not only in the forms but also in the generations and the successions of every species. At this time, at all events—whatever he may have been later—Buffon was fairly outspoken in the expression of even heterodox hypotheses; it was only subsequently that he was condemned by the Sorbonne, on account of opinions propounded in his "Théorie de la Terre," contained in the same volume as the preliminary discourse. It is significant, moreover, that at this date he saw no hint of any evolutionary significance in the homologies of the vertebrate skeleton; he had as yet learned nothing from comparative anatomy. This is shown in the argument by which he defends his own method of arranging species—a method which wholly ignored anatomical considerations and merely proceeded from the more familiar to the less familiar animals.

> Is it not better to make the dog, which is fissiped, follow (as he does in fact) the horse, which is soliped, rather than have the horse followed by the zebra, which perhaps has nothing in common with the horse except that it is soliped? . . . Does a lion, because it is fissiped, resemble a rat, which is also fissiped, more closely than a horse resembles a dog?[15]

It is probable, then, that in writing the opening discourse of his great work Buffon was innocent of any idea of organic evolution; it is certain that he did not convey that idea in any such way that a reader of his time might be expected to recognize it. Nor did he make any use of the conception of the descent of species in his "Théorie de la Terre," of the same date—where he might naturally have been expected to introduce the doctrine, if he held it; on the contrary he implies (p. 197) the equal antiquity of all species—though he does so in a way which, I confess, might plausibly be taken as ironical. The truth is that when under the influence of the principle of continuity Buffon's mind overshot the problem of the origin of species altogether. There were no such things as species: upon this point he was clear. There was therefore no need of explaining their genesis. As for the further question, how successive generations of offspring are related in form to their forebears, that was a question upon which the principle of continuity had, strictly speaking, nothing to say. That offspring varied somewhat, and usually slightly, from their parents every one knew; to this extent the conformity of the laws of heredity to the law of continuity was a common-place of every-day observation. Beyond this, no definite genetic or embryological consequences seemed necessarily to follow from the maxim *natura non facit saltus*.

The most important thing, however, to remark concerning Buffon's position in his first volume is that it is a position which he speedily

[15] "Hist. Nat.," Vol. I., p. 36.

abandoned, and to which he never returned.[16] Its most characteristic point was the contention that nature knows only individuals and that species are *entia rationis* merely. The most characteristic point of nearly all his subsequent references to the subject is the contention that species are real entities, definable in exact and strictly objective terms, and necessary to take account of in any study of natural history.

This change already was manifest in the second volume, published in the same year as the preliminary discourse (1749). In this volume Buffon propounded his celebrated definition of species, which was destined to have so great an influence upon the biological ideas of the later eighteenth century.

> We should regard two animals as belongng to the same species if, by means of copulation, they can perpetuate themselves and preserve the likeness of the species; and we should regard them as belonging to different species if they are incapable of producing progeny by the same means. Thus the fox will be known to be a different species from the dog, if it proves to be the fact that from the mating of a male and a female of these two kinds of animals no offspring is born; and even if there should result a hybrid offspring, a sort of mule, this would suffice to prove that fox and dog are not of the same species—inasmuch as this mule would be sterile (*ne produirait rien*). For we have assumed that, in order that a species might be constituted, there was necessary a continuous perpetual and unvarying reproduction (*une production continue, perpétuelle, invariable*)—similar, in a word, to that of the other animals.[17]

This language, it will be observed, implies not only that species are real entities, but also that they are constant and invariable entities. The same implication may be found again later in the volume; Buffon thus concludes the exposition of his embryological hypotheses—which embraced a theory of pangenesis:

> There exists, therefore, a living matter, universally distributed through all animal and vegetal substances, which serves alike for their nutrition, their growth and their reproduction. . . . Reproduction takes place only through the same matter's becoming superabundant in the body of the animal or plant. Each part of the body then sends off (*renvoie*) the organic molecules which it can not admit. Each of these particles is absolutely analogous to the part by which it is thrown off, since it was destined for the nourishment of that part. Then, when all the molecules sent off by all the parts of the body unite, they necessarily form a small body similar to the first, since each molecule is similar to the part from which it comes. It is in this way that reproduction takes place in all species. . . . There are, therefore, no preexisting germs, no germs contained within one another *ad infinitum;* but there is an organic matter, always active, always ready to be shaped and assimilated and to produce beings similar to those which receive it. Animal or vegetable species, therefore, can never, of themselves, disappear (*s'épuiser*). So long as any individuals belonging to it

[16] Rádl's account, already quoted, of Buffon's attitude towards transformism and towards the conception of species, is apparently based chiefly upon the first volume. For virtually all of Buffon's views, except his early and quickly repudiated one, Rádl's statement is almost the exact reverse of the truth.

[17] "Hist. Nat.," Vol. II., 1749, p. 10.

subsist, the species will always remain wholly new. It is as much so to-day as it was three thousand years ago.[18]

The reference here is primarily to the continuance rather than the invariability of species. But the latter seems also to be implied; and certainly Buffon does not improve the opportunity to introduce a hint of the doctrine of mutability—as he could hardly have failed to do if he had at this time held that doctrine and had been desirous of propagating it. It must be remembered that these passages also were written before Buffon's opinions had been censured by the Sorbonne.

No account of Buffon's position in the history of biology can be other than misleading which fails to note the decisive significance, for nearly all of his positions from the second volume onward, of the peculiarly Buffonian criterion of identity and diversity of species. Unless this criterion (and the implied distinction between species and varieties, which latter term covers many Linnæan species) be borne in mind, most of the pages in the "Histoire Naturelle" which have an evolutionistic sound are likely to misinterpreted. This is what has happened in a number of the studies of Buffon's relation to evolutionism. The error is especially conspicuously in Samuel Butler's "Evolution Old and New." Butler has devoted nearly one hundred pages to a review of Buffon's utterances on the subject; yet he nowhere lets his reader know that Buffon was the propounder of a new definition of species, which set up a radical distinction between species and varieties, and implied that a species was a definite, objective, "natural" entity. The oversight is not due to any neglect of Buffon's to emphasize and reiterate his definition. He recurs to it frequently in later volumes. His sense of its importance was such that the question of hybridism and the limits of fertility in cross breeding was one of the very few subjects which he can be said to have studied experimentally on his own account. He writes, for example, in 1755:

We do not know whether or not the zebra can breed with the horse or ass; whether the large-tailed Barbary sheep would be fertile if crossed with our own; whether the chamois is not a wild goat; . . . whether the differences between apes are really specific or whether the apes are not like dogs, one species with many different breeds. . . . Our ignorance concerning these questions is almost inevitable, as the experiments which would settle them require more time, care and money than can be spared from the fortune of an ordinary man. I have spent many years in experiments of this kind, and will give my results when I come to speak of mules. But I may as well say at once that I have thrown but little light on the subject and have been for the most part unsuccessful.[19]

[18] "Hist. Nat.," Vol. II., p. 425.

[19] Vol. V., p. 63. The passage is given by Butler, but he shows no sense of its general significance.

(*To be concluded*)

A WORLD-WIDE COLOR LINE

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ONE phase of the declining birth-rate among the white peoples of European stock has become increasingly important now that world interests have begun to override national and continental interests. If mere numbers should turn out to be the determining factor in fixing the balance of world power the European peoples can not hope much longer to retain the hegemony which they have held since the period of wider colonization began. The whites have not themselves become stationary in numbers, but the extension of white influence into regions inhabited by colored races has increased the prospect of a large growth among the latter. Those agencies which have kept down the natural increase of non-European peoples are usually either eliminated or very greatly modified when white rule is established or when white civilization comes to exert a preponderating influence. In Africa, for instance, the slave trade and intertribal wars have been practically abolished in those districts which have come under adequate European control.

To the extent also that the salutary achievements of European civilization have been accommodated to native modes of living, material conditions have been so modified as to furnish an environment theoretically favorable to a greater economy of human life. Because in most instances this influence has been as yet only a casual one, and because many of the race contacts have occurred in regions and under conditions least favorable to good results, the saving of life has not been so marked as it might otherwise have been, but on the whole the influence of white civilization has been a notable factor in population economy among primitive peoples.

There are of course some important exceptions to this rule. If white civilization does not everywhere and always counteract Malthus's "positive checks," misery and vice, it is because the attempt to adjust primitive peoples to a more complex economy is sometimes destructive in itself. Many of the most wholesome conveniences and comforts of the European are disastrous to peoples accustomed to a simpler or at least to a different economy. Nansen claims that the Eskimo of Greenland have been demoralized by the introduction of fire-arms, bread, coffee and cloth as much as by European diseases.[1] Mr. Bryce states that the adoption of European styles of housing and clothing, those pet items in the program of the militant philanthropist, has literally decimated the natives of Hawaii since Captain Cook's time.[2]

[1] Nansen, "Eskimo Life," pp. 328–331.

[2] Bryce, "The Relations of the Advanced and Backward Races of Mankind," p. 11.

To these influences should be added the diseases, before unknown, which the whites have carried with them. Tuberculosis, small-pox, syphilis and alcoholism have proved peculiarly destructive to primitive peoples accustomed to a mode of life which brings the effect of such diseases to a maximum. Until proper medical service and adequate sanitary safeguards are secured, this heavy penalty for the fruits of civilization must continue to be paid. The change to a settled, orderly mode of living and to a new food economy may also often bring about a physical deterioration as baneful as specific diseases.

European colonization in regions occupied by backward races often results in the violent destruction of native populations in the struggle for territory. The Dutch settlers in South Africa are said to have regarded "shooting off the black stuff" as their first task in fitting the land for occupation. Whatever the government may have intended, it is certain that the English colonists in Australia have in many instances deliberately slaughtered the blacks on the pretext of safety. Writing of conditions as they existed thirty years ago, Carl Lumholtz says:

> There are instances where the young men of the station have employed the Sunday in hunting the blacks, not only for some definite purpose, but also for the sake of the sport; the blacks have been killed by poison. A squatter at Long Lagoon in the interior of Queensland achieved notoriety by laying strychnine for the blacks, and thus taking the life of a large number in a single day. . . . The result of this is that in the frontier districts there is still being waged a war of extermination between the two races. Any savage discovered by the white man runs the risk of being shot. Poison was laid in the way of the blacks once while I was in Queensland.[3]

In certain instances like Tasmania and Cuba, European colonization has led to the complete extinction of the aboriginal population as a separate group, and in other instances, like those of the Maoris of New Zealand and the Hottentots, the native population has been very greatly depleted. Most of these disastrous results have come to peoples, generally blacks, in the lowest stages of culture. Where the aborigines are more advanced and hence more pliable they have usually profited by contact with Europeans. As a consequence several colored races are now enjoying considerable prosperity, due to the removal of the worst checks to their growth. The negroid peoples exhibit an amazing power of multiplication when protected from destructive forces. Negrophobe critics are wont to go so far as to hold that this is the sole important capacity which the blacks possess. The race is taunted with being by nature and capacity *proletarii* in the most primitive sense of the term —mere breeders.

While the yellow races are not so characteristically prolific as the blacks, they have, in several conspicuous instances, emerged on the modern field not only with a more elaborate culture, but with a denser

[3] Lumholtz, "Among Cannibals," pp. 346–347.

population within their natural habitats. Roughly speaking, eastern Asia is already peopled almost to the limit under present conditions, while tropical Africa is but sparsely populated in proportion to its capacity. Under favorable conditions of economic efficiency tropical Africa would be the home of nearly a billion blacks. Taken together, and allowing for a normal growth, these two ethnic groups may possibly increase in numbers until they shall cause the whites of Europe and America to dwindle into insignificance by comparison.

This is the thesis of a recent significant book by B. L. Putnam Weale, an authority on far eastern politics.[4] The peril of white supremacy arises, Weale believes, not alone from the growing balance of numbers in favor of the colored, great as that is likely to prove, but from the fact that the colored races are beginning to acquire and will continue to gain a distinct race consciousness and a sense of race solidarity. And just as the narrow interests of the little Greek lands were supplanted by the wider outlook of Alexander's empire, as the peninsular civilization of republican Rome was swallowed up in the world dominion of the imperial period, so the continental system of modern Europe is being swept into the whirl of world-wide interests. In this great historical change the ethnic element, or, more specifically, color, is to be the militant factor. With the increase of intelligence the aggressiveness of the colored races will augment and they will begin to take conscious advantage of their weight of numbers. A readjustment of power must follow as fast as the colored races become efficient in the arts that make for group self-assertion. For, says Weale:

> Real frontiers—real barriers to the swaying to and fro of peoples—are no longer rivers or mountains or seas or any of those physical features still referred to in the geography books. These are only the frontiers of savages; the real frontiers of civilization are formed by masses of men distributed in proper density, highly civilized, irrevocably locked to the soil by their history and their culture, and sufficiently warlike to make their physical boundaries respected should wanton aggression menace them. . . . A deep instinct will continue to push men to substitute for the purely political demarcations which have come down from other days a new class which may be called racial demarcations. That such demarcations are necessarily blurred is no matter; this only adds one more difficulty to a question which force may attempt to solve. It is this knowledge—that racial instinct and racial pride ignore political boundaries—which is the nightmare of statesmen.[5]

The colored already outnumber the whites of the world nearly two to one, and this proportion is likely to increase rather than diminish in the immediate future. Weale estimates that by the year 2000 China will have eight hundred million population and Japan one hundred and twenty to one hundred and forty million. As race consciousness grows more pronounced war must constantly occur as the colored races be-

[4] "The Conflict of Color," London, 1910. Weale is the pseudonym of Mr. B. L. Simpson.

[5] *Ibid.*, pp. 90–91.

come stronger in offensive ability and attempt to win back piecemeal what they have lost in the past while still "undrilled." "That they must become at least masters of their own houses can not any longer be doubted." [6]

Against this alarmist view two objections may properly be offered on the score of population increase. In the first place, as the colored races approach the standard of the white civilization, the same influences which have reduced white fecundity will increasingly operate among them. As has already been shown, improved modes of living are already making possible a greater population economy among the colored, and the acquisition of still higher standards will lower the birth-rate to a point consistent with these better standards of living. Secondly, it is not at all true that the expansion of the white race has now reached its final geographical limits. Not to assume that certain elevated districts within the tropics may in time be open to white colonization, there are still vast areas in Siberia, South America, South Africa and Australasia so sparsely settled as to be practically uninhabited. It is therefore nearer the truth to say that the habitat of the colored races is now fixed beyond the possibility of notable change except by sporadic migrations, while the greater regions at present sparsely peopled are within the white sphere of influence.[7]

COLORED

	Per Square Mile.
China	266
Japan	320
British India	211
Java	600

WHITE

	Per Square Mile.
United States	25.6
Canada	1.48
Argentina	5.4
Siberia	1.4
Australia	1.5
Cape Colony	8.7
Transvaal	10.0

That there already exists, since the rise of Japan, a well-marked sense of race solidarity among the yellow peoples of eastern Asia need

[6] Estimating the total population of the world at 1,705,000,000, Weale makes the division by color as follows:

Whites	566,000,000
Mixed whites	40,000,000
Absolute yellow, brown and black	1,099,000,000

Of the whites 453,500,000 are assigned to Europe, and of the colored 947,000,000 belong to Asia and 140,000,000 to Africa (p. 111).

[7] The density of population in certain of the greater habitable areas peopled by the whites and by the colored outside of Europe shows some significant contrasts:

not be disputed, but that this will long remain the basis of eastern Asiatic politics is not certain, or even probable. The Japanese alliance with England shows how feeble are ethnic as compared with purely national interests in international relations. The negroid peoples, although they have made little progress towards a distinct race consciousness, are beginning to show glimmerings of a sense of ethnic unity, or at least a consciousness of separateness from the whites. After the Russo-Japanese war a vague rumor that a white race somewhere had been beaten in war by a colored people filtered into very remote portions of Africa. During the Boer war news of British defeats spread with incredible rapidity among the blacks and was everywhere received with exultation. Among the blacks of South Africa the colored churches are found to very soon cast off their alliance with white churches and to insist on separate ecclesiastical organization. This so-called "Ethiopian" movement, it is interesting to note, is fostered by the negro churches in America, with which in several cases definite alliances have been made.[8]

Weale's alarm call to the white race is based on the assumption that the whites as whites are likely to be faced by the colored races in solid array. He calls attention to the fact that the European nations are disunited and can not act harmoniously in either Asia or Africa, and that they will be so hopelessly outnumbered in the near future that even united action would leave their position hazardous. Now it may be possible that we are to see a great development of geo-politics, so that the cry "Asia for Asiatics," or "Africa for Africans," will unite the peoples of those continents in solid mass. But geo-politics must not be confused with ethnic politics; and if considerable independent white groups should arise in Asia or Africa it is probable that they would be among the foremost in resenting European domination. Nor is it likely that the yellow and black races will ever find common ground of union among themselves and against the whites, just as it is unlikely that the white peoples will always remain disunited in the face of a real peril. To assume such a danger is to suppose that the ethnic element will continue to constitute the important factor in world politics that it now does. It is much more reasonable to believe that economic and cultural interests will ultimately supplant purely ethnic interests as the groundwork of world contacts.

The real kernel of the color problem, then, is likely to continue to be what it is at present, the question of social contact among peoples of different racial stocks, and particularly of different cultural levels, living together within given political areas, rather than a struggle of independent racial masses against each other. In America there is a wide-spread belief that our color problem is one peculiar to

[1] See the report of the South African Native Races Committee entitled "The South African Natives," Ch. VII.

ourselves. As a matter of fact, the race struggle covers the whole world, wherever whites and blacks are brought together under common political and social forms. It is the struggle of a highly differentiated, efficient civilization with one more simple and primitive. This struggle results from the differing powers of adaptation of the two races, Racial characteristics are the accompaniments rather than the cause of lack of adjustment.

Since the elements of the problem are simple and fundamental and since they are everywhere essentially the same, it is to be expected that the color struggle should follow similar lines in various parts of the world. The antipathy between the whites and Indians in America from the earliest period of colonization to the present, the very terms in which this antipathy was expressed and the methods of conflict on each side, have been duplicated in the struggle between the English colonists and the natives of Australia, Tasmania and New Zealand. And at the present moment the political and social elements of the race problem in the southern States of America are almost identical with those in the South African colonies.

It has been the misfortune of white civilization in its contact with the colored races in America, Africa and Australasia that both its worst products and its least desirable representatives were the ones first in the field. This has been an important factor in shaping the early relations of the races. It is the rover, the outlaw and the irresponsible trader who come first, and it is too often the contraband goods of civilization that they carry. It has been the rougher type of white also who has intermarried with native women and become the father of a hybrid progeny. Curiously enough, it is among this rougher class of whites that the worst type of race animosity exists. Where the cultural rank has been more nearly equal and where the contact has been of the organized rather than sporadic type, the mingling of the races has generally been accompanied by little confusion or social disintegration.

It goes without saying that there is a varying degree of adaptability and fusing power among the different branches of the white race in their relations with backward peoples. The Latin peoples in Europe have shown peculiar capacity for successful inter-marriage with tropic races. Spaniards have crossed with fair success with both Indians and negroes in America and with Malays in the Philippines, as have the Portuguese with the two former types in Brazil. Undoubtedly the Catholic Latin peoples have shown peculiar capacity for merging with colored peoples and manifest less color prejudice than do the Protestant Teutons. This is due, no doubt, in part to physical facts, but a more important factor is the insistence of the Roman Catholic Church on the solidarity of the world's peoples and its deprecation of race prejudice. In the Spanish and French West Indies there is a greater proportion of mixed marriages than in the British West Indies and there are fewer evidences of social friction.

While the antipathy of white toward black is the most pronounced phase of color conflict, prejudice against the blacks is not confined to Europeans and Americans. The Chinese, the most cosmopolitan of peoples, sometimes exhibit a striking aversion to taking black wives or concubines, but manifest no particular aversion to the native women of Java or Borneo. East Indian laborers imported into the British West Indies and British Guiana have generally refused all intercourse with negro women. The American Indians have sometimes interbred with blacks, but in British Guiana they are reported to despise the negroes and to have little intercourse with them.[9]

It is sometimes asserted that a rigid enforcement of the color line in the tropics would leave the two races isolated in an intractable antipathy. Sir Sidney Olivier, governor of Jamaica, has argued from this that a middle class of mixed stock serves as a useful buffer between white and black. He says:

> Where, therefore, we have created and are developing a community of diverse races, I can not, in the light of British West Indian conditions, admit that interbreeding is necessarily an evil. I think, rather, that where we have such a community we had better make up our minds not only not to despise the offspring of illicit interbreeding that invariably takes place in such conditions, but make our account for a certain amount of legitimate and honorable interbreeding and to look upon it, not as an evil, but as an advantage.[10]

But such interbreeding, Sir Sidney maintains, should invariably come about by the marriage of white men with colored women. There is a good biological reason for this, but the primary consideration is the racial welfare of the whites. Whatever the good qualities of the negro, and Sir Sidney sees more of them than most of his fellow whites, he nevertheless thinks that

> the white races are now in fact by far the further advanced in effectual human development, and it would be expedient on this account alone that their maternity should be economized to the utmost. A woman may be the mother of a limited number of children and our estimate of the number advisable is contracting; it is bad natural economy, and instinct very potently opposes it, to breed backwards from her. There is no such reason against the begetting of children by white men in countries where, if they are to breed at all, it must be with women of colored or mixed race. The offspring of such breeding, whether legitimate or illegitimate, is, from the point of view of efficiency, an acquisition to the community and, under favorable conditions, an advance on the pure-bred African.[11]

A mixed stock, however, while it may lessen the actual clash between the two extreme types in a community, does not necessarily diminish the totality of race antagonism, and may augment it. For the hybrid, instead

[9] Johnston, "The Negro in the New World," pp. 331, 332 and 334.

[10] Olivier, "White Capital and Colored Labor," pp. 39–40.

[11] *Ibid.*, pp. 37 38.

of commanding the confidence of both parent stocks, usually himself becomes the object of animosity on the part of both, and this is an added danger to social peace. Ostracized by both races, he is particularly hateful to the more backward type. Mixed breeds usually possess greater mental capacity than the pure blacks and are the victims of the latter's jealousy.[12] This is in harmony with the familiar social law that in a given society made up of hostile classes it is the nearest, and particularly that next above in the social scale, which is most cordially hated. Jealousy of hybrids is due chiefly to two causes. They are, except in the United States, more freely admitted to social privileges, and it is with them that the dominant race is more likely to contract marriage. In the United States, where any appreciable intermixture of blood exists, the mongrels are enumerated as negroes, while in nearly all the other countries mixed breeds constitute a separate and often a privileged class.

To characterize the negroes merely as a passive race, as is often done, does not fully cover the situation. It is more nearly correct to describe them as pliable and imitative. Ability to bend and adapt has proved the negro's salvation in the supreme test of contact with complex and often rigid white institutions. In marked contrast stands the American Indian whose "grand refusal" has been his undoing. Not only has the negro of the new world survived transplanting, but he has everywhere taken on the cultural tone of the particular white group with which he has been brought in contact. In Spanish America he has acquired the taste in dress and the pride bearing of the Castilian. In Haiti he is essentially French and in Brazil Portuguese. The impress of France is still on the negroes of Louisiana and the Jamaican negro is unmistakably British.

In other words, the negro reflects by imitation the civilization of the society in which he lives. His character in any mixed society depends largely on the social standards which others set. Originally brought into touch with European civilization without any fixed cultural equipment of his own, he develops in social capacity along the lines of least resistance, reacting to such stimuli as the social environment offers. But while lacking in positive cultural achievement he possesses certain well-developed temperamental traits which enable him to fit into some social environments better than others. He is sensuous, and his esthetic nature is richer on some sides than that of the north European. It can hardly be questioned that the Latin temperament is better adapted to harmonize with the negro than is the less volatile Teuton.[13] Just as the American

[12] See Prichard, "Where Black Rules White: Haiti," p. 280; also Kirke, "Twenty-five Years in British Guiana," pp. 260–262.

[13] Oliver asserts that the negro is naturally more courteous than the lower classes of northern Europe, and he is convinced that the insolence of the American negro is due in large measure to the bad manners and unwarranted pretensions of the whites. "White Capital and Colored Labor," pp. 46, 48.

negro feels an instinctive admiration for southern white people, in preference to unemotional northerners, so the race has in the course of generations reacted more spontaneously, and perhaps more wholesomely, to the vivacious Latin temperament than to the sterner Teuton type. The smaller degree of race friction in the Latin colonies may point to a possible modification of world policy in the white man's growing problem of dealing with black races in Africa and Australasia.[14]

This tendency of the negro to take on the psychic tone of the dominant culture may have far-reaching results in Africa itself. Weale is convinced that if the African negro shall be Mohammedanized the fate of the white man's empire in that continent will be sealed. From the Arabs the negro would acquire an aggressive, war-like spirit that would ultimately lead to his mastery of his own continent. If, on the other hand, the Africans are christianized they will remain docile. But, as already noted, the negro temperament is little adapted to aggressiveness or independent activity. It is therefore more probable that he will develop in civilization, if he develops at all, on the lines of the European peoples who are pressing on the more remote portions of Africa with ever-increasing persistence.

Wherever the blacks are massed in undisturbed possession of the soil, their contact with the whites is in the nature of independent group antagonism. In tropical Africa the true negro is at home, and, so far as can now be foreseen, the white man can rule only as an outsider without constituting any appreciable element in the social population. But on the fringes of the continent the situation is very similar to that in the United States, where a ruling race is settled upon the same soil and is capable of self-perpetuation. But even in temperate South Africa it is possible that large political units, wholly black, may survive. The South African black, except in Cape Colony, is not at present granted equal political rights, but if he continues to progress in intelligence as he has recently done his demand for political and social equality must become exceedingly strong, as it has in the United States; and the struggle for equality will of itself be a means of developing a fixed sense of race separateness which must long make the color question a sore spot in South African politics.

In the Australian commonwealth the color problem exhibits a most peculiar and interesting phase. The aboriginal inhabitants scarcely figure in the question at all. There can, for the present, be little idea of their active participation in organized social interests, both by reason of their small numbers and because of their absolute lack of capacity. It

[14] Sir H. H. Johnston points out that the hold which the French secured on the negroes of the Windward Island and of Dominica during the period of their occupancy was deeper than that which the English have been able to acquire during the period of British rule. "The Negro in the New World," pp. 233–234 and 306–309.

is the colored immigrant, whether black, brown or yellow, who furnishes the problem. This new commonwealth, with a native black population regarded as negligible, has deliberately set out to develop an exclusively white civilization on Australian soil, even at the expense of a dearth of labor force. So powerful has the "White Australia" movement become that stringent exclusion laws have been passed by the commonwealth parliament denying admission to all non-British immigrants unable to pass fixed educational tests, and providing for the deportation of numerous colored laborers already present on contract. How passionate the "White Australia" idea is, and how deeply it deplores the evils of race mixture in the rest of the world, is manifest in the words of its most scholarly exponent, Professor Charles H. Pearson:

> Australia is an unexampled instance of a great continent that has been left for the first civilized people that found it to take and occupy. The natives have died out as we approached; there have been no complications with foreign powers; and the climate of the South is magnificent. . . . We are guarding the last part of the earth, in which the white races can live and increase freely, for the higher civilization. We are denying the yellow race nothing but what it can find in the home of its birth, or in countries like the Indian Archipelago, where the white man can never live except as an exotic.[15]

Such a policy of white segregation, if it were sound, would be an example of the thing which nations ought to undertake more often than they do. It represents a deliberate choice of ends planned for long in advance, and it is an admirable case of what Lester F. Ward calls "social telesis." But this paticular policy happens to be one which is open to serious question. It never has succeeded, nor is it likely to prosper in Australia, because the aggregation and composition of populations are governed by laws of selective fitness which are stronger than statutes. Certain areas in various parts of the world are almost certainly destined to belong primarily to the whites, as certain districts of Africa and of the United States may come to be recognized as the special habitat of negroes, but the selection must come in the first place from natural fitness rather than law, and the area is never likely to be continental in extent.

The island of Cuba exhibits the curious spectacle of a tropical land which is peculiarly fitted to be the home of a colored race, but which is for the time being swinging towards a decisive white majority. After 1898 it seemed that Cuba was to follow the steps of Haiti and become a black republic, but immediately after the war of liberation there set in

[15] Pearson, "National Life and Character," pp. 16–17. For details of the "White Australia" movement, see Scholefield, "The White Peril in Australasia," in the *Nineteenth Century* for August, 1905; and Law and Gill, "A White Australia: What it Means," in the sàme periodical for January, 1904. The law of 1901 excluding colored labor was entitled "The Pacific Islanders Act." The final limit for deporting the contract laborers was fixed for December 31, 1906. To prevent the destruction of the sugar industry in Queensland a bounty is offered on sugar grown by white labor.

an active and steady immigration of Spanish peasants which in ten years has amounted to 128,000.[16] Gradually overborne by numbers, the negroes are beginning to segregate, and in 1908 a party of color was formed. While there is as yet no definite color caste in social life, the supplanting of Spanish influence by American ideas will doubtless gradually assimilate conditions in Cuba to those of the neighboring states of America.

In the last analysis color prejudice is based on cultural difference more than on the degree of pigmentation. Because extremes of physical difference do actually in large measure accompany difference in culture rank, the most radical race antagonisms are those between the extreme whites and the extreme blacks. A black skin is everywhere associated in thought with cultural inferiority. Back of this may lie a subconscious suggestion of the historical fact that the negroid races have achieved few of the cultural values that are to the white man the marks of superior mental and social efficiency. To the extent that the blacks live down this stigma of cultural inefficiency prejudice against them will lose its force. There are abundant evidences of color aversion on the part of the white towards the yellow, brown and red races, but it nowhere reaches the intensity of that directed against the blacks, nor is it of sufficient depth to constitute a fundamental social problem.

Speaking particularly of race antagonism in South Africa, Mr. Bryce says:

> The sense of his superior intelligence and energy produces in the European a sort of tyrannous spirit which will not condescend to argue with the native, but overbears him by sheer force and is prone to resort to physical coercion. Even just men, who in theory have the deepest respect for human rights, are apt to be carried away by this consciousness of superior strength, and to become despotic if not harsh. And the tendency to race enmity seems to lie very deep in human nature. Perhaps it is a survival from the times when each race could maintain itself only by slaughtering its rivals.[17]

It is therefore by narrowing the gap between the actual cultural status of the races that the worst aspects of race animosity are eliminated. Whether, as Boas and Ward hold, the total mental capacity of all races is essentially equal, is not here the question. Achievement of any valid kind, whether by individuals or by racial groups, is bound ultimately to command respect. World contacts are rapidly increasing and a higher degree of intergroup cooperation is making possible a wide diffusion and sharing of the achievements of each of the great racial groups. When this process shall have gone far enough much of the asperity which has characterized the periods of isolation will be materially softened.

[16] "Censo de la República de Cuba," 1907, pp. 59–66; see also Johnston, "The Negro in the New World," p. 60. The census of 1907 shows that in a total popuulation of 2,048,980 the colored number 608,967, or 29.7 per cent. The unmixed negroes number 242,382.

[17] Bryce, "Impressions of South Africa," p. 366.

It is an unquestionable fact that the yellow as well as the negroid peoples possess many desirable qualities in which the whites are deficient. From this it has been argued that it would be advantageous if all races were blended into a universal type embodying the excellences of each. But scientific breeders have long ago demonstrated that the most desirable results are secured by specializing types rather than by merging them. The perfection of individual qualities insures a high degree of general efficiency in case those qualities can be coordinated in a systematic organization. This is particularly true of human types. The doctrine of racial Darwinism no longer implies a struggle in which the defeated type is exterminated. Under conditions prevailing in modern civilized association it implies rather an application of the selective principle through a combination of competition and cooperation, by which the superior qualities of each race are sifted out and brought to efficiency. It implies also a rough sort of interracial division of labor.

A group of negro leaders in America have advocated the principle of a "group economy" for the colored people of the south, and the idea is capable of a wider application to the great racial groups of the world. In a world of free exchange and intergroup cooperation it is absurd to suppose that the white race can get the benefit of whatever is useful in the tropics, for instance, only by conquest and colonization. Perhaps it is true that the tropical peoples will become efficient only through the influence of organized white leadership, but Mr. Kidd's plausible plea that the white race ought to master and hold the tropics "in trust for civilization" is an empty phrase unless it means a real overlordship. The question inevitably arises, "Whose civilization?" For when the colored races shall have developed an adequate race consciousness it is inevitable that they should seek to devise their own institutions according to their needs, and from the point of view of world interest it is desirable that they do so.

The color line is evidence of an attempt, based on instinctive choice, to preserve those distinctive values which a racial group has come to regard as of the highest moment to itself. Although sometimes based on a blind prejudice surviving from the primal instincts of periods of isolated savagery, it invariably, in its better phases, has in it the core of a sound scientific truth, which is that specialization is the law of efficiency. The fact that it is always the lighter race that puts the taboo on the colored, and that the latter is everywhere eager to mix with the whites, is only an evidence of the general trend of choice towards the higher efficiency of the white race.

THE CROSSING OF THE RACES

By Dr. J. G. WILSON

NEW YORK CITY

A Study of the General Principles governing the Successful Intermixture of Different Peoples, with special Reference to the Question of Immigration into the United States.

THE question of racial amalgamation is almost as old as the race itself. For, not only the earliest traditions, but also the most ancient relics bear witness to the fact that extensive intermarriage of races had been brought about through commerce and war long before history had begun to unravel the tangled skein of man's wanderings.

The crossing between different tribes, which was commenced in prehistoric times, has been continued into our own era with ever increasing speed and complicity of results. For man has always been a migratory animal, and the improved changes in means of transportation and the ever-widening fields of commerce have increased rather than diminished this inborn tendency.

Looking over the world at large, and throughout all time, we see that the results of racial intermarriage have been exceedingly variable. Sometimes it has produced a better race. This is especially true when the crossing has been between different but closely allied stocks. The Englishman who has resulted from the commingling of so many Teutonic tribes with the native Briton and Celt, and the composite molded and directed by Roman culture, is perhaps the very best example of a good result from extensive crossing. Likewise the cross which has taken place in Ecuador, Mexico and Peru has produced a race not altogether hopeless so far as the future is concerned; for, however much it may have hurt the Spaniard, it certainly has improved the Indian immeasurably. It is not so much a question of the *possibility* of producing a vigorous cross race under favorable conditions, as it is a question of whether such a cross is, in itself, a *desirable* thing.

There are those who profess to believe that the incoming hordes of southern Europeans and the Alpine races will never mix their blood with us to any appreciable extent, and will always remain foreign in race as well as in ideals. Judged in the light of history, such an opinion is without firm foundation. It is not conceivable that the modern Greek, who is himself such a mixture of Serbo-groation, Slav and ancient Greek stock, can have any irrevocably inborn tendencies which will prevent him from eventually mating with our own people if given the opportunity. The German will marry any woman of any white race. The Italian will do the same. The Alpine races have intermarried to the north and south of them until their mental traits shade off almost imperceptibly into those of the German and Italian. As a general rule, marriage between different branches of the white races is not governed by laws essentially different from those governing individuals of the same branch. It is chiefly a question of proximity of the sexes and the lapse of sufficient time to make the mutual desires mutually understood.

The vital question is, whether this inevitable amalgamation is worth the fostering care and regulation of our government. The answer to this question depends altogether upon what will be the results of this immigrant blood upon our own individual selves and upon our social and political institutions.

In regard to the influence upon the individual physical type, we often hear it said that we are becoming a smaller and a darker race; that our average stature is less than it used to be, and that we are becoming dark eyed and dark haired, instead of the race of tall blonde we once were; and there is a tendency to blame the immigration of the last half century for this alleged change in physical characteristics. If such a change is taking place, it should be attributed to the influence of our climate rather than to the effect of blood admixture. The stature and complexion of a people seem to be determined, in the long run, more by the locality and climate in which they live than by any other influences, although it takes many generations for that physical type to be finally evolved which is best fitted to the climatic conditions of its particular locality. Once evolved, the type remains fairly constant for the given region. Judging the future by the past, we should not expect the tall blonds of northwestern Europe to permanently survive in the United States. There is scarcely a trace of the physical traits of the conquering northern hordes left upon the general mass of the population of Italy or the Alpine regions of Europe. The colony of Swedes which settled along the Delaware in our own country have entirely disappeared. The Scandinavian, according to Dr. Karlsen, who has made the subject a matter of special study, rapidly deteriorate, physically and mentally, under the changed climatic conditions which he encounters in his new home in the northwest of our own country, and no less an authority than Woodruff, believes that he will soon die out in the United States unless active measures are taken to offset the baneful influences of a climate to which he is temperamentally and physically unsuited.

In evolving the type of man physically fitted to best survive in a given locality, nature seems to work according to some mysterious laws entirely beyond human control. This is exemplified in the population of modern Egypt, where the mass of the people as represented by the villagers along the Nile and in the country districts, conform almost exactly in physical appearance to the colored portraits of the ancient

Egyptians on the walls of the tombs of the kings of Thebes. In other words, 4,000 years of changing religions, ever-shifting political conditions, and the inroads of commerce and war with their continual introduction of alien blood have not served to materially alter that physical type, which, during the countless ages of prehistoric time, had been gradually evolved as best adapted to the climatic conditions of the valley of the Nile. It may then be concluded that the influence of immigration upon our physical type will, in the long run, be nil. *That type of man best adapted physically to the climate and soil will, in the point of numbers, eventually predominate in spite of all restrictive legislation or man-made laws of any kind.*

When we come to consider the question of the influence of racial amalgamation upon our *habits* of *thought,* upon *our morals,* and upon *our institutions*—upon our spiritual selves, we are confronted with a much graver problem, and one over which we have at least some little power of control. This is really the serious problem which we have to solve, for, after all, it is not so much difference of blood relations that produces enmity among the component peoples of a nation, as it is the difference of political and social ideals, and history is replete with instances where nations have lost their own peculiar form of civilization and political institutions on account of overwhelming alien influence. That the influence of the alien in the United States is enormous, and that it is becoming yearly more and more important, is an almost self-evident proposition.

In order to arrive at a fairly intelligent opinion as to whether or not this influx of foreign thought and social habit will ever change sufficiently to conform to our own standards, we should study the history of the nations from which it comes, and whose ideals it has already helped to form. Is there anything in the past history of the countries from which our immigrants are now being chiefly recruited to justify the belief that they will eventually sympathize with our political institutions and with those Anglo-Saxon habits of thought which we must insist upon as necessary to good citizenship in a great republic? A brief study of the leading alien type will demonstrate the principle upon which the research necessary to answer this question should be conducted.

Let us first consider the case of the Italian. Here we may be tempted to at once pass an unfavorable opinion on the ground that he is, by virtue of previous training and habits of thought, at entire variance with republican ideals. Such a judgment will be hasty and hardly warranted by the premises. When we remember what the Italian has accomplished for himself at home since 1820, when the first real agitation for a free and united Italy may have been said to have commenced, it should encourage us in the belief that he is capable of sustained and intelligent efforts for the common good.

Whereas Italy was once a conglomeration of petty states and absolute monarchies, torn by warring factors, and her people steeped in universal illiteracy, she now, through her own efforts, under the intelligent leadership of children of her own soil, has become a constitutional monarchy with the real power legally invested in the people where it by right belongs. Through his prime minister, the king is responnsible to the chamber of deputies, which corresponds to our lower house, and are elected by the people at large.

The senate is probably as truly representative as our own, being elected by the king from the ranks of the ex-deputies, the nobility, large taxpayers and representative men of affairs.

When we consider that for fifty years preceding her final unification and freedom Italy was in an almost constant turmoil of political agitation and war, it is remarkable what advances her people have made in the thirty-nine years since the accomplishment of her great ambition. Although she still ranks high among the illiterate, she has taken great strides to overcome that evil. An education law compelling the attendannce at school between the ages of six and nine, and the teaching of illiterate soldiers, although they may not as yet have accomplished great things, show that her heart is right, and that time will fast remedy the evils which the exigencies of her struggle for existence have practically forced upon her.

The study of the Italian in the Argentine ought to give us an inkling of his possibilities when given an opportunity. This republic is modeled on lines almost exactly after our own, and, all things considered, should rank as a successful experiment in self government. Its people are happy. It enjoys a high degree of culture. Its cities are modern and well governed, and its commerce is ever increasing in dignity and volume. Now, relative to its whole population, Argentine has the largest number of Italian immigrants of any country in the world. In 1895 the total population was about 4,000,000, and one third of this was foreign born. Of this foreign born population 500,000 were Italians. This enormous Italian influence still holds its own, for since 1895 it has kept up almost constantly, and for the whole period of time elapsed since she became a republic in 1853 nearly half her foreign born population has been contributed by Italy.

We should not allow the evil deeds of certain bands of outlaws, and the criminal tendencies of certain of the lower classes to blind our vision to the great things accomplished by the Italian as a nation. Viewed in the light of her past history and her rapid advances of the present day, she promises well, and it is a fair prophecy that in our own country the future citizen of Italian forebears will only be distinguished from the general average by means of his family name remaining as a sign to indicate his original ancestry.

The possibilities of the Slav, and his aptitude for conformity to the ideals of western civilization, can not be adequately treated without an exhaustive review of the history of the nations of eastern Europe. However, a short résumé of Polish characteristics will suffice to give an idea of the type of the race and result which may be expected from the great wave of Slavic immigration now sweeping over us.

For the two hundred years succeeding the close of the fourteenth century, Poland was the leading power of eastern Europe. Her 20,000 square miles was the seat of what was, to all intents, a vast republic, for, though her elective king was responsible only to her nobility, this nobility was so large and so accessible and eager to maintain the political equality of all its own members, that the constitution, though it conferred rights only upon the privileged classes, carried out in reality the idea of almost unlimited freedom for the individuals of that class. Had this very numerous nobility of freedom born a still larger proportion to the total population, the self government of the nation would have been an accomplished fact, for the ideas of political reform and the extension of privileges to all classes were already beginning to make themselves felt when Poland was caught between the upper and nether mill stones of foreign tyranny, and her national identity crushed out forever by the treachery of Prussia and the soldiers of the Russian throne. Since the last partition of Poland in 1795, her people have not been given the chance to exercise the capacity for self government which they had undoubtedly developed to a high point when overtaken by the series of misfortunes which resulted in the loss of national identity. There are many reasons to think that this capacity is not wholly dead, but only lies dormant, awaiting the propitious changes of fortune. At the same time it must be conceded that the Pole possesses, in common with all Slavs, a peculiar combination of eastern and western ideals that makes his fitting into an Anglo-Saxon civilization a problem of great complexity. For, while he loves political freedom almost to the point of insanity, he is easily caught by the glitter and pomp of a throne. Confiding by nature, the mere promise of the unscrupulous Napoleon was sufficient to make him offer up his life upon many a bloody battle field.

As the Poles are, individually, poor business men, easily imposed upon by the commercially minded Hebrew, to whom the generosity of a political asylum was time and again extended when he was driven and harried from almost every other country in Europe, so are they, in the aggregate, poor political economists, and have thus always been worsted in the fields of diplomacy as well as in trade. Whereas they possess the greatest intellectual gifts, being almost universal linguists, and contributing great names to literature and science, they are apt to be versatile rather than profound, and are prone to waste their efforts in unpractical fields of endeavor. Though courteous and brave, their love of individual freedom is sometimes carried to the point of anarchy, and when guided by unscrupulous leaders this tendency often shows itself in riotous uprisings which are entirely out of proportion to the grievances against which they are directed. However, the Slav has one redeeming feature which, if properly utilized, might, in time, offset these undesirable characteristics. This feature might properly be called his *great willingness to learn new things.* He is not clannish. He has no innate deep-grounded instinct against getting acquainted. Naturally diffident and retiring on account of long centuries of class distinction, he is not prone to make the first advances, and consequently, if left to himself, he will tend to congregate with his kind. But his children quickly make friends with ours, and the foreign parents never discourage this tendency. Considering the short time that he has been with us, and his ignorance of our language, he has shown a marked tendency to amalgamate, and so long as we allow him to come at all, we should encourage this tendency, for although very different from us in his natural habit of thoughts and intellectual gifts, these differences are not of a kind that tend to produce moral or intellectual deterioration, and from a physical standpoint he will add to, rather than subtract from, the efficiency of our race.

The Slav and the Hun have been associated together so long in Europe, and their immigration to this country has been, in each case, extended over practically the same period of time, that it is quite the natural thing to consider them both together when making a study of their special race characteristics and possibilities of amalgamation. However, it is more a community of interests and political institutions than it is a racial identity that makes us class them together and speak of the Slavish and Hungarian immigrant as practically of the same kind. In reality these two stocks are essentially different and have shown rather wide differences in their respective abilities to adopt the ways of western civilization. The true Hungarians or Magyars are a Mongolian or Turanian stock. They left their Asiatic home about 1,000 years ago and descended upon Europe as a barbarous horde that for fifty years struck terror into the hearts of the neighboring inhabitants of Germany and Italy. Finally the Germans conquered them and they were almost at once forced to accept the alternative of western civilization or racial extermination. They chose the former, and immediately they demonstrated a high degree of adaptability to democratic political institutions. They united with the other kingdoms of eastern Europe to stay the march of the Ottoman Turks, and come in for a full share of credit in the series of events which finally resulted in the naval battle of Lepanto in 1571, when the long struggle between the two opposing religions for the possession of Europe and the consequent mastery of the world was forever settled in favor of christianity. Thus we see that the Hungarians not only adapted themselves to western ideals, conforming to the manners and customs and religion of the people about them, but they became the greatest active exponents of these ideals, and for over 500 years they were the main defence of Christian Europe against the Turkish tribes of Asia that followed closely in their footsteps.

Manifestly the western civilization thus upheld by the Asiatic Hungarian in eastern Europe is different in many ways from Anglo-Saxon or Germanic culture. Whereas a high degree of individual liberty has been the aim of both, the one has succeeded in attaining its goal by making self sacrifices and compromises for the common good, while the other has not yet attained complete freedom, largely because of a failure to understand the essential differences between liberty and license. In Hungary to-day we have a sad example of this seeming lack of ability to forget individual differences for the common good. In the eastern half of the monarchy, a Hungarian minority holds the non-Magyar races in just such political serfdom as they themselves were subjected to before 1866, when the Prussians established the preeminence of Germany in Austria. And yet, in all fairness, we must not too hastily assume that the Teutonic races have a monopoly of that political unselfishness which makes self government possible.

The Pole might justly say that the rebellion of the barons and the Magna Charta, which they exacted from King John, and which we are inclined to consider the first great step in the establishment of political equality was, in reality, no different from the republic of nobles in their own land, for, in each case, the mass of the people were little better off than before, both being left in a condition of practical serfdom. And the Hungarian might almost with equal truth say, that he is no more domineering over the non-Magyars in eastern Hungary than is the German minority over the Czechs in Bohemia, and the Poles in Gallicia. Whatever may have been the cause, the fact remains that the Irishman at home has never been able to attain any higher degree of political equality than the Pole or Hungarian, yet the Irish descendants of the immigration of fifty years ago have absolutely amalgamated with us, and now conform to the highest type of American citizenship.

The final amalgamation of the Slav and Hun with our native stock is a foregone conclusion, but what the final effect will be depends largely upon the time taken to complete the alloy. Were it possible to so regulate the numbers of the new arrivals that they would never be in excess of the number of their children attending our public schools, the problem would easily adjust itself, for then we should always have more real Americans in the making than we have non-Americans in reality. A study of the history of the Hun and Slav, and a careful analysis of their respective national characteristics, seem to warrant the conclusion that they are both amenable to the ways of western progress, and that we have more to fear from their great numbers than we have from any undesirable qualities inherent in themselves.

And now we come to consider the other type of immigrant which is making itself so strongly felt in our land and which, if we are to judge by the history of other nations, will continue to be an unsolved and vexatious problem long after the Pole and the Hun and Italian are forgotten. The Jew has been a source of worry and discomfort to every nation in which he has ever settled in *any numbers,* unless we except our own. *Whether this is his own fault, or the fault of the people among whom he has cast his lot, is entirely beside the question. The point to be determined is, whether he will, or will not, in time, lose his racial identity and mix with the general population around him.* Is there anything to warrant the conclusion that he has at last found his haven in this country, and being left free to practise his religion without persecution, will become one of us in every sense of the word, except in the matter of religious belief, which is, after all, a matter of no great importance so far as citizenship is concerned. Let us answer the question in the particular instance by ascertaining how it has been solved, in the aggregate, during times already past, and then considering whether there are any essential differences in the conditions of the past and present. The first historical account of anti-semitism occurs in the book of Esther, third chapter and eighth verse—"And Haman said unto King Ahasuerus, there is a certain people scattered abroad and dispersed among the people of all the provinces of thy kingdom; and their laws are diverse from those of every people, neither keep they the King's laws: therefore it is not for the King's profit to suffer them." We all know the sequel to this speech, and how the contemplated massacre and expulsion was obviated by the wiles of the beautiful Esther. The story of this attempted expulsion of a whole race of people, almost at the dawn of history, would have no particular interest for us now had it not been the forerunner, so to speak, of like movements repeated with almost dreary monotony throughout all the centuries since. That anti-semitism is not a modern movement, having its essential cause in the crucifixion of Christ, but was, on the contrary, a well-defined policy of many nations long before the question of christianity arose as a complicating factor to confound the real issue, is a fact attested to by the Jewish historians themselves. We learn from Josephus that there were considerable Jewish colonies in all the eastern towns and among the various Greek possessions. They lived an exclusive life, mingling but little with the people, and having their own customs and laws which they refused to abandon at any price: although at utter variance with those of the Greeks about them, the authorities were continually called upon to settle disputes arising between the Jews and the people among whom they settled. Thus, in the year 14 B.C., the Ephesians requested that the right of citizenship be taken from the Jews if they would not consent to join in the worship of Diana. Nicolas, of Damascus, pled the cause of the Jews and they won the suit. Now, among all the nations of antiquity the citizen was bound to be of the same religion as his city, but the profession of this religion called for very slight obligations so far as *belief* was concerned. In matters of faith, the Greek colonies were not at all exacting. It was this very eclecticism which the Jews seemed to hate and made him break with the world about him. The result was that he almost always asked that he be granted *special privileges,* and almost invariably got them. At the same time he was very careful to insist upon having his common rights, so the result was that he was almost universally hated throughout all the great cities, and was constantly compelled to seek a renewal of his privileges. Very much the same story is repeated in the Byzantine Empire, in Ostrogothic Italy, in Frankish and Burgundian Gaul and in Visigothic Spain. In all these countries the Jew was at first admitted without prejudice, and received on the grounds of political and social equality. In all these countries he subsequently became the object of hatred and persecution.

During the middle ages, when the Jew was truly a wanderer upon the face of the earth, and he scarcely knew which way to turn, he found safe haven in the Kingdom of Poland: in fact, for one hundred years after the charter of King Boleslas in 1264, the Jews had the privilege of mixing freely with the Polish population, and even after the modification of the charter they were never wholly cut off from this privilege. Although Poland never actually persecuted them, and for a long period of time really treated them on an equality with her own people, they have never, as a body, taken any interest in any of the great political and national questions with which she has been so continuously agitated. The German colonist, settled long after the Jew, has lost every trace of his nationality but his name. The Stuarts and O'Rourke's, who sought refuge in the republic from a hostile government, have become as ingrained in the Polish community as the Pole himself, but the Jew is still a stranger.

In France, the Jews enjoyed equal privileges until long after Christianity became an active issue. In Spain they were first admitted on equal terms. The same in England. In all these countries they finally became disagreeable to the mass of the people and restrictive legislation was directed against them. As late as 1879 Germany experienced an active anti-semitic movement. When the cause of the modern anti-Jewish feeling is analyzed, it seems to have about the same basis that it had before the time of Christ. In both cases it has been at bottom essentially a question of manners. The Jew, as a class, is different from the people among whom he has settled, and he has insisted that he be given certain special privileges which serve to emphasize the difference rather than obliterate it. In other words, he is inherently clannish. Wherever this clannishness has been forgotten and he has laid aside, or kept in the background, the customs and mannerisms which mark him as a peculiar person, he has been a welcome addition to the land of his adoption. However, he has refused to do this except in individual instances. As a class, he has, as a matter of principle, refused to intermarry with those of other religions.

This raises the question, How can a people amalgamate and fit into the general populace when they refuse to take the one step absolutely essential to complete amalgamation? Protestants of all denominations can intermarry and still maintain their standing in their respective churches. By the exercise of a few essentially trivial formalities, protestant and catholic can intermarry and both remain good protestant and good catholic, but let the Jew marry the Gentile and the Jew is at once branded by his co-religionists as a bad Jew.

Those of his race who have conformed to the apostolic injunction, when in Rome to do as the Romans do, have always been a credit to the land of their adoption. But the tendency to adaptation has, so far, been developed only on a small scale. There does not seem to be a general movement of sufficient momentum to encourage the belief that the Jew, forgetting his race and remembering only the essential principles of his religion, will finally arrive at the goal of complete racial amalgamation. True, there is a marked tendency among the adherents of reformed Judaism in the United States to bury the antiquated customs of the past and to become real Americans, but this reformed Judaism hardly has time to make itself felt before it is dealt a killing blow by the mere force of numbers in the opposite ranks. In other words, the old ideas from the ghettos of Europe are imported so rapidly that the new has but a poor chance to gain sufficient adherents to keep pace with, and finally outstrip, the old superstitions. And this thought brings us to the final conclusion of the whole matter, and that is, whatever the race of people from which the immigrant comes, the final result is not to be feared so long as he does not come in overwhelming numbers. If he trickles in slowly we shall take care of him. Let him be what he will when he comes, the amalgamation will finally be complete. On the other hand, if we continue to let him come in what is practically unlimited numbers, we can not take care of him. He will take care of us. We shall lose our inherited Anglo-Saxon ideals, and instead of a perfect amalgamation, we shall confront the danger of a complete racial substitution.

THE CONSERVATION OF THE FOOD SUPPLY

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THE maintenance of the food supply is the basal problem of civilization. Before commerce or manufactures or mining can be carried on—before science or art or religion can flourish—man must be fed.

Hitherto, the people of the United States, thinly scattered over a country of vast extent and seemingly exhaustless fertility, have scarcely realized that there is such a thing as a food problem, but more and more frequently of late there are heard warnings of the danger of an inadequate food supply for our future millions and of the resultant peril to our democracy through the fostering of caste and class distinctions. That the problem is a serious one, even if it be not so immediately imminent as some would have us believe, admits of no reasonable doubt.

Now the problem of food supply is in essence a problem of energy supply. Food yields the energy which operates the bodily mechanism and upon the regularity and sufficiency of this energy supply depends absolutely all human endeavor. To produce those carriers of energy which we call foods is the chief function of the farmer. By means of the green leaves of his crops he entraps the energy of the sunlight and stores it up in the starches, fats and proteins of his wheat, corn, etc., to be liberated again in the body when these are used as food. The farmer as a food producer is the first link in the chain of human activities—the agent by whose labors the boundless stream of solar radiation is utilized for man's service—and the density of population which a country can support from its own resources is practically limited by the amount of solar energy which the farmer can recover in food products.

Clearly then in preparing to meet the future food problem the primary thing is to see to it that the farmer is taught how by means of tillage, fertilization, seed selection, crop rotation, and all the arts of good farming to accumulate as much as possible of the solar energy in his yearly crops. The proposition is sufficiently obvious and already commands popular support.

There is, however, another less evident aspect of the question. In order to feed the teeming millions of the future, it will not only be necessary to fix as much of the solar radiation as possible in the form of crops, but also to utilize the energy which the latter contain with the maximum of efficiency. When our population reaches half a billion, there will be little margin for waste.

Now in view of our absolute dependence on solar radiation, it is a rather startling fact that but the smaller part of the energy stored up in the farmer's crops is directly available for man's use. Of that of the wheat crop, for example, fully sixty per cent. is contained in the straw and another 10 per cent. is rejected in the process of milling as bran and other by-products. In other words, only about 30 per cent. of the energy stored in an acre of wheat is directly available for human nutrition. Much the same thing is true of most other food crops, while the grasses and clovers, so important in all systems of agriculture, are, of course, entirely unavailable as food for man. Hitherto, our enormous surplus of food products has served to obscure the significance of this fundamental fact. Not only have we been able to export vast quantities of breadstuffs to less fortunate lands, but we have used other millions of bushels of edible products, especially corn, as food for domestic animals. America has been a country of cheap animal food—meat, eggs, milk, butter, cheese, etc.—and we have been fond of drawing the comparison between the abundant meat supply of our working classes and its comparative scarcity in the diet of the European laborer and, rightly or wrongly, have attributed much of the greater industrial efficiency of our workmen to this difference in diet.

But we are rapidly approaching an economic limit to the production of meat from edible grains. Such a conversion is an exceedingly wasteful process. Of the solar energy stored up in a bushel of corn, less than 3 per cent. is recovered in the edible portion of the carcass of the steer to which it is fed, while even in pork production this percentage scarcely rises to more than 16, and in milk production to about 18, and similar losses are observed in all branches of animal production. In other words, the stockman who feeds his animals on grain is expending energy available for human use as fuel for his animal machines for the sake of recovering a small fraction of it in higher priced and more palatable products, a process which can hardly fail to remind one of the reputed origin of roast pig. So long as our food supply was vastly in excess of our needs, such practises were doubtless economically justifiable. To the solitary hunter in the primeval forest it was a matter of comparative indifference whether he made his camp fire of underbrush or of the best grade of timber, but with lumber at its present price, the mill owner can afford only sawdust and refuse to feed his fires. In the past, speaking broadly, our meat production has consisted to a large extent in the exploitation of our food resources. There has been a choice between producing bread *or* meat, and the improvements in stock husbandry have been largely in the direction of more profitable exploitation. In the near future, we shall have to reverse this attitude and study the conservation of the food supply. Not much longer can we continue to take the children's bread and cast it to the brutes. If our abundant meat supply is to be maintained, it must be in some other way. With such a density of population as we may reasonably expect, it will no longer be a question of producing bread *or* meat, but of producing bread *and* meat. All the edible products which the farmers' acres can yield will be needed for human consumption and the function of the stock feeder in a permanent system of agriculture will be to utilize those inedible products in which so large a share of the solar energy is held and to render at least a portion of the latter available for human use. Meat and other animal products will be produced, not as luxuries for the tables of the rich, but as a means of conserving energy for human use, both directly through the food thus rescued from waste and indirectly by setting free edible plant products for man's use. The stock feeding of the future will be a very different matter from the simple grazing of cattle in summer or the lavish feeding of corn in winter. It will be a highly artificial process, dealing with feeding stuffs unfamiliar to the fathers and seeking to utilize to the utmost the energy of every available by-product. It will call for a degree and a kind of knowledge and skill far exceeding that which has sufficed in the past.

Until within a comparatively few years, but little direct study has been devoted to these fundamental considerations, especially in the United States. While institutions for agricultural research have flourished, they have either concerned themselves with the more obvious problem of increasing crop production or else, in response to the demands of stockmen, have devoted their energies largely to seeking more efficient ways of converting corn into meat. In this latter respect, they have aided in exploiting rather than in conserving food resources, and it has been difficult to secure public interest or public funds for fundamental investigation looking toward the conservation of the food supply of the future.

More than a purely scientific interest, therefore, attaches to studies of the principles governing the utilization of the stored-up energy of feeding stuffs, particularly of by-product feeds, such as have been made during the past ten or twelve years by German investigators, particularly by Kellner at the Moeckern Experiment Station, and as are now being prosecuted by the Institute of Animal Nutrition of the Pennsylvania State College in cooperation with the Bureau of Animal Industry of the United States Department of Agriculture.

Such a study is far from being a simple matter. Essentially, of course, its method must consist in feeding the products under investigation to animals and ascertaining what proportion of their energy can be thus saved. The difficulty lies in the determination of the latter point. This must be accomplished with an accuracy and a degree of detail unattainable in the ordinary feeding experiment if the conclusions are to pass beyond the empirical stage and lead to the establishment of general principles. For this purpose Kellner has used a form of the so-called Pettenkofer respiration apparatus, first devised many years ago by Professor v. Pettenkofer in Munich, while the Pennsylvania institution employs an instrument known as the respiration calorimeter, first devised by the late Professor W. O. Atwater for investigations in human nutrition and which has been enlarged and modified to adapt it for experiments upon domestic animals.

The central feature of both apparatuses consists of an air-tight chamber through which a measured current of pure air passes and within which the animal stands in a comfortable stall, where it can be fed and watered at will. The total energy contained in the feed of the animal is ascertained by determining the amount of heat which a sample of it produces when completely burned, while the energy escaping in the visible excreta is measured in the same way. Furthermore, by analyzing samples of the air-current before and after its passage through the chamber containing the animal the gaseous waste products given off by the latter are determined.

Finally, energy escapes from the animal in the form of heat. In the German experiments the amount of heat produced by the animal is virtually computed from the amount and kind of materials oxidized in the body. This may also be done in the experiments with the respiration calorimeter, but in addition this apparatus is provided with appliances for the direct determination of the heat given off, it being taken up by a current of cold water circulating through copper pipes and its amount measured with the aid of sensitive thermometers. In this way the total income and outgo of the animal can be compared, the difference showing how much of the energy of the food has been stored up as meat or fat, while a comparison of the observed with the computed heat production serves as a check on the accuracy of the experiments.

The method is not unlike that employed in locomotive testing plants like, *e. g.*, that of the Pennsylvania Railroad at Altoona. Just as in the latter, the heat value of the fuel is measured, so in the experiments upon the animal the heat value of the feed, which is the fuel of the animal body, is determined. The losses in the visible excreta of the animal may be compared to unburned coal dropping through the grate, while the gaseous excreta correspond to the flue gases. A large amount of heat is given off in both cases, and the final balance of income and outgo makes it possible to trace exactly the use which the locomotive or the animal makes of the energy supplied to it.

The material or ration to be tested is fed for some three or four weeks with the greatest regularity. During the latter portion of this time, after the effect of the ration has become fully established, the animal spends from two to five days in the respiration apparatus or the

CHEMICAL ELEMENTS AND ENERGY OF INCOME AND OUTGO PER DAY

	Water		Nitrogen		Carbon		Organic Hydrogen		Energy	
	Income Grams	Outgo Grams	Income Grams	Outgo Grams	Income Grams	Outgo Grams	Income Grams	Outgo Grams	Income Calories	Outgo Calories
Consumed										
3,000 grams Timothy Hay	175	—	34.5	—	1,213.2	—	183.1	—	11,691.5	—
300 grams Wheat Bran			8.1	—	117.0	—	18.0	—	1,180.4	—
900 grams Corn Meal	318	—	13.0	—	377.3	—	51.7	—	3,323.9	—
900 grams Linseed Meal			49.5	—	384.1	—	54.5	—	3,913.8	—
10,180 grams Water	10,180	—	—	—	—	—	—	—	—	—
150.6 grams Hydrogen Oxidized	1,355	—	—	—	—	—	—	150.6	—	—
Excreted										
7,756 grams Feces	—	6,198	—	31.3	—	699.9	—	93.5	—	6,855.6
5,360 grams Urine	—	3,846	—	69.0	—	100.5	—	17.7	—	1,017.7
22 grams Hair and Brushings	—	—	—	1.6	—	9.4	—	1.3	—	103.8
102 grams Methan	—	—	—	—	—	76.2	—	25.4	—	1,359.8
3,563 grams Water Vapor	—	3,563	—	—	—	—	—	—	—	—
3,831 grams Carbon Dioxid	—	—	—	—	—	1,044.7	—	—	—	—
Heat Produced	—	—	—	—	—	—	—	—	—	9,338.5
Gain by Animal										
19 grams Body Protein	—	—	—	3.2	—	10.1	—	1.4	—	109.4
145 grams Body Fat	—	—	—	—	—	110.8	—	17.4	—	1,375.6
Loss by Animal										
1,579 grams Water	1,579	—	—	—	—	—	—	—	—	—
Error	—	—	—	—	—	—	—	—	50.8	—
	13,607	13,607	105.1	105.1	2,051.6	2.051.6	307.3	307.3	20,160.4	20,160.4

454 Grams = 1 Pound.

calorimeter under the constant observation night and day of three or four skilled men. Its intake of food and energy, the losses in the excreta, the volume, composition and temperature of the air passing through the apparatus and in the case of the respiration calorimeter especially the temperature of the water used to take up the heat produced are matters of continuous record. A single "run" with the latter apparatus involves the recording of nearly 7,000 observations, while fully 25 samples of various sorts are taken whose subsequent analysis in the chemical laboratories involves the making of some 150 determinations.

From the results of these hundreds of weighings, records and analyses there is finally worked out a complete balance of income and outgo.[1] Comparisons of these balances on different amounts and kinds of feed, with different animals, and under varying conditions, permit exact conclusions to be drawn regarding the nutritive effects of the rations consumed.

The investigations in progress relate to three different aspects of the general problem: First, how do different feeding stuffs compare with each other as to their content of energy and the proportion of it which is available to the animal? Second, what is the relative efficiency of different types of animals as converters of waste energy into human food? Third, how do the various conditions under which animals may be kept affect their efficiency in this respect? To the extent to which it becomes possible to answer these questions for the different species of farm animals we shall possess the scientific basis for a rational system of conserving to the utmost for man's use the energy which the studies of the chemist, the physicist, the botanist, the agronomist and the soil expert have taught the farmer how to accumulate in his crops. The investigations are, therefore, in reality a study of the conservation of the food supply, a problem even more fundamentally important than the conservation of our mines, forests or water powers, and one which vitally concerns the welfare not of the farmer alone but of the whole people.

[1] On page 500 is an example of such a balance sheet.

THE MORAL INFLUENCE OF A UNIVERSITY PENSION SYSTEM

By Dr. HENRY S. PRITCHETT

THE CARNEGIE FOUNDATION FOR THE ADVANCEMENT OF TEACHING

WHILE a college or university can not divest itself of a humane duty towards an old or worn-out teacher, it does not follow that every college is under an obligation to establish at once a system of retiring allowances. The obligation for a service performed is one thing; the question of taking on general obligations for services to be performed is quite another. It is fair, however, to say that it is the clear duty of a college at our present stage of civilization to reckon among its obligations those to old and worn-out servants and to deal with these obligations in full view of all other duties. Hitherto colleges have in the main admitted no such duty. The educational corporation has generally acknowledged no obligation to the individual when his services were no longer wanted. This attitude is no longer possible. No corporation under our social and industrial order can brush aside this humane duty. Every such organization must, as best it may, do its duty both to the public and to the individual. For this reason, therefore, no college is justified in turning out without some provision an old and faithful teacher who has long served it. It still does not follow that such an institution is in a position to establish a permanent and definite system of pensions.

The questions, what form of pension system is wise and just, and what effect the establishment of a pension system will have upon the professional and moral qualities of teachers, and what effect the establishment of such a pension system will have upon the college itself, still remain to be answered. These questions are part of a much larger one with which society is to-day engaged. Is it for the interest of society as well as for the interest of the individual that some definite provision for old age and disability be made? If so, under what conditions should such pensions be conferred and from what source shall they be provided? Should the beneficiary bear at least a part of the burden of a pension or should it be paid by the agency, whether it be corporate or governmental, which the pensioner serves? These are questions with which all modern organizations—state, business corporation or social organization—are confronted. The college or university, as one of these organizations, must also seek to answer these questions in its own way and to the extent of its responsibility.

The literature which has appeared in recent years concerning pensions is large. In this country the most valuable contribution to the subject has been the Report of the Massachusetts Old Age Pension Commission, a report due in large measure to the energy and careful work of its chairman.

Pensions, as we discus them to-day, are characteristic of modern civilization. This is necessarily so. A pension system can not be valued unless it promises security, and it is only within recent history that institutions and governments have attained to any great degree of security. In the ancient world pensions are hardly met with except in the bounties paid to discharged soldiers. In the Middle Ages the church, the only stable institution, fixed no age limit for its servants, but relieved their old age by coadjutors and assistants rather than by retirement.

The modern pension systems appeared in the nineteenth century and have shown rapid growth. Their extension to all orders of society has been a feature of the opening decade of the twentieth century. This result is due to two facts: first, to our quickened sense of humanity; secondly, to the clearer appreciation that such humanity means more effective service and an improved condition of society. Minor factors have also helped to quicken the attention of the more thoughtful nations to the need of support for old age. The work of modern society is done under increased pressure and under more nervous conditions. At the same time that these changes have taken place improved public hygiene has lengthened our years beyond the average of the last century. Men's activity is exhausted at an earlier date in many callings, while at the same time improved conditions of health prolong their lives. The period in which men require help has, therefore, been extended.

The movement for a general system of pensions to aged poor, to be paid by the community, was first proposed in England in the eighteenth century. The first comprehensive plan, however, to be enacted into a national law was that adopted by the German legislation of 1891. This was followed by Danish legislation in the same year; and at the present time, in addition to these countries, France, all the Australian states, and New Zealand have old-age pension systems, while Belgium and several of the cantons of Switzerland maintain a voluntary insurance against old age. In 1898 England enacted in Parliament the most far-reaching of all old-age pension acts.

The United States government has hitherto lagged behind other nations in the investigation and study of the civil pension for its old servants. This is no doubt due in part to the prejudice against all pensions engendered by the history of the bounties bestowed by the government upon the survivors of the Civil War and their families. The payments on these pensions aggregated in 1910, forty-five years after the close of the Civil War, the enormous total of $160,000,000.

The history of this pension fund has been perhaps the greatest scandal which has fastened upon our government. This enormous payment represents not devotion to the patriots of the Civil War, but political truckling in its smallest and most objectionable form. With this lesson before them the people of the United States have hesitated to deal at all with the question of pensions for civil servants.

Notwithstanding the unwillingness of the national government to deal with the question of civil service pensions such pensions are being widely extended amongst the large business corporations and railroads. The New York Central Railroad, the Pennsylvania Railroad, the United States Steel Corporation, and many other railroad, banking and industrial corporations have established systems of pensions for their officers and employees. An interesting type of such a system has recently been authorized for the Boston and Maine Railroad by the legislature of Massachusetts. In addition, several states of the union, the last of which is Wisconsin, have inaugurated pension systems for public school teachers, maintained in considerable part by deductions from the salary of the individual.

Before the establishment of the Carnegie Foundation, pension systems for teachers, quite limited in their provisions, were in operation in the University of California, Columbia University, Cornell University, Harvard University, McGill University and Yale University. Pension systems have since been instituted in Haverford College and for those teachers connected with Teachers College at Columbia University who do not come within the rules of the foundation. In most of these colleges the entire pension was to be paid by the institution. In some of them—as, for instance, at Cornell—the pension was to be paid in part from an endowment fund and in part from the payments of the professors.

The various pension systems thus briefly alluded to as now being in operation may be divided into two general types, the non-contributory and the contributory, and the latter type must be subdivided into two subtypes—that in which the contribution of the prospective pensioner is voluntary and that in which the contribution is compulsory. It goes without saying that the variations under these types and subtypes are endless. For example, in the compulsory contributive type contributions may be required from others than the pensioner himself. Thus, the German old-age pension system regards three parties as participating—the imperial government, the employer and the employee. The last two contribute equal amounts. In the year 1907 the contributions were as follows:

Imperial government	M49,600,620
Employers	89,321,600
Employees	89,321,600
Total	M228,243,820

In other words, the total expense on account of old age pensions in Germany for that year amounted approximately to $57,000,000, of which the state paid something over $12,000,000—an interesting contrast to the enormous expenditure of the United States upon war pensions in the same year, the difference arising in the main from the fact that one expenditure was made under a carefully thought-out and carefully planned system, the other under an arrangement largely the result of accident modified by political considerations.

The relative wisdom of these different forms of pension systems has been the subject of sharp discussion during the past fifteen years. Out of this discussion one or two general principles appear to have been settled. The investigators of pension systems agree that the pension should be paid under definite and specific conditions, not as a matter of chance or of preference. A second conclusion to which practically all publicists have come is that the system under which a part of the pension is paid by the employing agency, but in which entrance to the pension system is a voluntary act, is a failure. Not that such a pension system will not accomplish good for many of those who enter it, but the very person it is instituted to relieve will not be affected by it. Such a system will, as a rule, fail either to relieve or to educate those lacking thrift, the very class most likely to need aid in old age. The experience of the past seems to show that one might as well expect all government civil servants to take out life insurance policies as to enter into such a plan for the relief of old age.

The discusion of pension systems at the present date, therefore, has practically settled down to the consideration of two systems: either one in which the contribution is compulsory upon all the prospective pensioners, or one in which the entire cost is borne by the regulating authority. It seems likely that in the future the development of pension systems by corporations or by governments will be along one of these lines, and this notwithstanding the fact that serious objections have been made and continue to be made to both plans.

If contributions are exacted from all, the contributors acquire rights which in some cases prove embarrassing to the administrators of the fund, if that administration be a government or a corporation. For example, great difficulty was found in dismissing certain dishonest police officers in New York City, because by their contributions to the pension fund of the force they claimed a vested right in their office. This, of course, is an extreme case.

It has also been shown by experience that in a contributory pension system the employees will sooner or later make the following demands, which it is difficult for the employer to resist, and yet which greatly increase the cost of the pension system: (1) that if the employee resigns or is discharged his contributions shall be returned to him, with interest;

(2) that if the employee is disabled permanently through illness or accident before he arrives at the retiring age, he shall receive a proportional pension; (3) that if the employee dies before arriving at the age of retirement, his estate shall receive his contributions, with interest; (4) that if the employee retires, but dies before the total of his pension receipt equals the total of his contributions, his estate shall receive the difference, with interest.

The difficulties of maintaining a non-contributory pension system for a very large class of beneficiaries are also serious. No such system has been in existence long enough to afford much useful experience, and the estimates of experts are so affected by the lengthening of life in civilized countries, by the unforeseeable growth of the class to come under the pension system, and by that curious tendency for the average age in a community or a class to rise as the community or the class grows, that such a pension fund is liable to sudden and unexpected strains unless there are provisions for its increase from some large source—for example, government appropriations, or a supporting fund.

The difficulties of either of these systems are not insuperable. The doctrine of law which protects the contributor to a pension fund protects him only against what the law regards as arbitrary action and is difficult chiefly because it requires the management of the fund to proceed in all cases with a regard for legal precedent which laymen are apt to regard as excessive and which at times interferes with efficient management. If, however, justice and the necessary procedure of the law are adhered to, the compulsory contributory feature need not cause embarrassment.

The objection to the non-contributory scheme may be also obviated by economy, by a careful study of the laws of vital statistics of the class affected, by the general observance of just and fair management with the funds at the disposal of the managing agency and by the cooperation of beneficiaries themselves.

The practical question which faces those who are considering pension systems is, therefore, the relative advantages of the compulsory contributive type and of the non-contributory type. Both of these are immensely preferable to the unfair and inhumane system which they are intended to displace. Secretary MacVeagh has most clearly pointed out that, except with employers of peculiar hardness, all governments and institutions conduct their operations really on an imperfect pension system. The secretary writes in his report for 1909: "The service is blocked in many instances by the unwillingness of the officials in charge to throw out of place worthy men and women who have given the best of their lives to the work of the government. So that, in a very imperfect and wholly unsatisfactory manner, a pension system is, and long has been, in operation." Every college officer appreciates the fact that the colleges are also maintaining, in this imperfect sense, a pension system, but one qualified at every step by favoritism or partiality. One who has occasion to visit many colleges of the country will be astonished at times by two methods of procedure in this matter, diametrically opposite, and yet entirely to be reconciled with the methods under which our colleges are governed. He will be astonished in the first place at the inhumanity which will turn out an old teacher after long service with no means of support. He will be astonished in the second place at many institutions by the presence in the faculty of a considerable proportion of teachers who have long outlived their usefulness and who are practically pensioned by their retention in service. It is not one of the smallest of the disadvantages of this form of pensioning that the presence of the aged and the infirm often arouses in the minds of shallow and impatient men a disregard for the really superior qualities which many of those in advanced years possess. There are always those who believe under such circumstances that all evils can be remedied by a sweeping edict which often tears down more than it builds up.

The most serious objections brought against either the contributory or the non-contributory form of pension are two. Those who make the objections fear that pensions from an outside source may undermine the sturdy virtue of independence, and in the second place that the granting of such pensions and the security which may come from their anticipation will produce a decay of the fundamental virtue of thrift. To these moral arguments may be added the economic contention that pensions lower wages.

While there are certain differences between systems of pensions intended for working men and those intended for teachers, it nevertheless remains true that all these objections may be urged against a system of pensions for teachers with as much reason as against a system of pensions for working men. Human nature in teachers and in working men is in no sense different, and if these be sound objections in one case they are doubtless sound objections in the other.

The first of these objections seems to me to rest in large measure upon a false ground. A man can be independent and yet not insist upon paying himself for everything that he receives. In the complex organization of modern society no individual in any class of society pays for everything which he receives. The wealthy boy at college is a pensioner in very much the same way that the poor boy is. John Hampden lost nothing of his feeling of independence by partaking of the bounty of William of Waynefleet. Nor did Milton or Charles Darwin experience any impairment of their sturdy qualities of spirit from having been educated through the generosity of the Lady Margaret. That is a singular, and probably a narrow, man who has not partaken of the benevolence of others. The whole effect and outcome of that participation depends upon the spirit in which the benevolence is tendered and the spirit in which it is accepted. In a well-conducted pension system the administrators have in the main to come to a judicial determination as to whether a specific individual has complied with the conditions or not. If he has so complied, the awarding of the pension is very much like the payment of a salary.

Most persons who have thought concerning this matter feel much more strongly the argument that pensions discourage thrift than they do the objection that they cause a loss of independence. Thrift is a fundamental human virtue. Hard to build up in races and individuals, it is easy to break down in both. The true course in the training of human individuals and in the training of human communities would seem to be not to set thrift in opposition to the moral results achieved by a pension system, but to realize that the growth of thrift is analogous to the growth of all spiritual and moral faculties. It is just because the habit of thrift is so difficult to acquire and to retain that pensions are not antagonistic to it. The security given by a pension system is really the acquisition of a certain equity which will result in benefit to those who participate in it. Such a consideration, if rightly used, can be made to minister to the idea of thrift, not to break it down.

In fact, the whole theory that possible destitution in old age is the prime cause of thrift seems to need revision. Hope, not fear, is the great moving power in humanity. To save so that the income will be a decent support seems to many, and these often in highly respectable callings, so hopeless a task that to undertake it unaided appears foolish, but with a living assured in old age there is an incentive to save in order that additional pleasures or greater advantages for others might then be possible. It must, however, be admitted that the contributory type of pension lends itself more directly to the upbuilding of such a spirit than the non-contributory type. From the larger economic as well as from the larger moral standpoint the plan of a contributory pension seems to promise least danger to society and the greatest result. I am inclined to believe from such evidence as the pension systems which now exist can furnish that a justly regulated compulsory contributory pension system, on the whole, promises most both for the individual and for the social organization.

The economic argument that pensions depress wages is too vague to furnish any sound basis of objection. From the economic point of view the argument has weight, but in the actual administration of business so many factors influence wages that a pension, even if it exercised its influence on this side, must have a relatively small effect. It may be true that in certain cases the existence of a pension system may be used to persuade a man to enter a given calling and to undertake a given line of work for a smaller recompense on the ground that he is to receive a pension in the future. This argument certainly may apply to teachers as to all other classes of men who offer themselves for employment, but the experience of the foundation up to the present time indicates that this factor is relatively negligible. Since the inauguration of the Carnegie Foundation salaries of professors in colleges have steadily risen. The existence of a pension system in a college, while it may now and then be used to induce a man to undertake a particular work for a smaller salary, is nevertheless so small a factor that it does not count materially in the presence of other large factors in the matter of salaries.

The justification for a pension system, however, can not be found in its negative qualities, or in its comparative freedom from injurious results to the individual and to society. It must not only prevent suffering and inefficiency, but it must also raise the quality of service amongst those to whom it applies.

That a rightly administered pension system does this is already fairly proved. Particularly is this true where the labor of those under the system is mental labor, and still more when that labor is partly of a creative nature and upon subjects of no immediate concern to the individual. Anxiety and apprehension are the most deadly foes not only to mental exertion, but to the higher intellectual qualities of imagination and invention. A man may indeed put forth unusual intellectual effort for a few years in facing the problems of individual and family support, but to assume that concentration on such problems during a series of years, accompanied by distressing uncertainty as to his future, will help the quality of his teaching or his research is against human experience. Profitable study and the cheerful performance of severe tasks are aided by serenity, not perplexity of mind. Especially is this true of the fruitful period of middle life. If it be true that we are still so uncivilized that a prospect of serene and helpful old age is demoralizing to men of high intellectual training, then the cure for this situation does not lie in making old age uncertain and insecure, but in the gradual education of men to a better ideal of life. The experience of the Carnegie Foundation, short as it is, carries a strong argument in favor of the betterment in the work of the college teacher which comes from a knowledge that his old age is protected. Outside of all direct results to society arising from pensions, the argument drawn from humane and religious reasons probably will always appeal most strongly. The system of employment which uses the services of a highly trained individual at meager pay up to the point where he is no longer effective and then takes no concern for his welfare and for those dependent on him has a remnant of barbarism about it which arouses a protest in the conscience of civilized man. Our religious and our humane ideals demand that some effort should be made to solve this problem.

In all that has been said the systems of pensions under consideration have been those which arose gradually. For example, the system adopted by the German government came about after years of agitation and discussion. Pensions in the German universities began with the contributions of the professors themselves, and only after a long period of time and a long discussion of the economic and moral questions involved was the burden of pensions shifted entirely from the shoulders of the teacher to the purse of the government. The system of pensions supported by the Carnegie Foundation in the accepted institutions, in marked contrast to these, is one founded out of hand by the generosity of one man. It has inaugurated a series of pensions which are paid practically through the colleges, for the individual teacher has no occasion to know the Carnegie Foundation at all. He deals simply with his college.

Even when one admits the general good results flowing from a well-administered system of pensions, either upon the contributory plan or upon the non-contributory plan, there still remains the question, what is the moral effect of such a pension system as that which has been conducted during the last five years with the funds held by the trustees of the Carnegie Foundation?

The good side of this retiring allowance system is very easy to see. The letters which come from old teachers grown gray in the service of a modest college, speaking of the relief of mind and spirit which has come to them through this protection tell a story so full of human interest and of human happiness that there is no answer to such a recital. There is little danger that a pension will demoralize a man who up to sixty-five or seventy years of age has given his life to the hard and unselfish work of a teacher. Perhaps no feature of the Carnegie pensions has been more appreciated than that provision under which half of the pension of the teacher is paid to his widow. The meaning of this feature of the pension system was vividly stated in a letter which came to the foundation from the widow of an old college teacher in the middle west. Her husband had taught for forty years in a small college. He had accepted a year before a modest pension, and at his death the half of this pension, amounting only to fifty dollars a month, had been allotted to his widow. In acknowledging the receipt of the first payment she wrote, "Perhaps you can not understand how much it means to me to receive what some would consider so modest a sum, but with my little house in this small town this payment means the difference between dependence and independence." It is this which the teacher values most in his old age—independence for himself and for the wife who may survive him. The result of the Carnegie Foundation pensions in this direction has been all that one could wish.

No less evident has been the good effect of the foundation pensions upon the colleges themselves. Where the foundation has enabled a college to retire in a dignified and just way teachers who had worn out their usefulness and where it has enabled colleges to substitute in their place younger men of fresh and alert spirit, the result has been to quicken and vivify the whole intellectual life of the college. Here again is a result whose benefit no one can question.

On the other hand, there is another side which can not be lost sight of. The presence of the altruistic spirit amongst college teachers is strong, but perhaps no stronger than amongst other men. As in every calling a large number of those in the profession of the teacher are drawn to it by bread and butter motives. The offering of a pension can not fail in some cases to minister to the selfish side of human nature. There will always be certain individuals who, when they find themselves in possession of a given advantage, whether that take the form of a benefit in the hand or one to be acquired in the future, will trade upon the possession or the prospect of that benefit. There will be under such an arrangement a certain number of teachers who will count the years and the days until the coming of the minimum age which enables them to resign the duties which they now perform in a perfunctory and routine way. There are still other men facing responsibilities and difficulties in administrative places or in teaching who would gladly use the way of the pension to escape from the perplexities and responsibilities of their positions. Every president considers his own case an exceptional one. He is prepared to prove to the foundation, even when he is turned out of office by the trustees for alleged incompetence, that he is entitled to a pension on the ground of extraordinarily meritorious service. Every teacher, too, thinks his own situation is unique and that he is entitled to consideration of a special sort by reason of his particular and unusual service. All this arises out of the qualities of human nature. On the whole, the number of those whose selfishness is touched by such a benefit is small, as small perhaps as one ought to expect, and in the long run much of this will disappear as the teachers themselves become accustomed to a system of pensions. In time teachers will realize that it is to their own interest and in the direction of their own happiness to continue work as long as they are really fit and able to serve. The late William T. Harris always insisted that a college professor was at his best between the ages of sixty-five and seventy-five, and he strongly urged the trustees of the Carnegie Foundation at the inception of the trust not to make the minimum retiring age lower than seventy. Mr. Harris's argument was a partial one, but it had truth in it. There are many teachers who are at their ripest and at their best between sixty-five and seventy-five and such men ought, of course, to remain in their profession. In the long run it will be found that they will do so, although for a few years the idea of the pension will induce some men to surrender work at an earlier age than they ought. It is impossible to offer to men an advantage such as that which flows from a pension system of any sort without arousing in some minds the question—How can I get the most out of it? But the number of such individuals amongst college teachers is small and will become smaller as the standards of college life rise.

Nor can one shut one's eyes to the fact that the colleges themselves may, by reason of the pensions of the foundation, neglect their own duty in taking care of their old teachers. The officers of the foundation have done all in their power to make it clear to the colleges that the funds at their command and likely in the future to be at their command could care for only a limited number of colleges. Nevertheless, in spite of this effort, it has been tacitly assumed by many colleges, and generally by those of the lowest standards in scholarship, that any obligation on their part to care for their old teachers had vanished with the inauguration of the foundation. This phase of the situation is also, I believe, a temporary one.

One other feature of the Carnegie Foundation pensions has aroused criticism. This is the plan of a centralized pension fund and the fact that this agency deals in its publications with general educational questions which touch directly university interests and educational policies.

The dread of a centralized agency in any field of social activity is one which depends largely on the point of view of the individual. The idea that such an agency as the Carnegie Foundation will exert arbitrary pressure upon those colleges which choose to accept its pensions seems to me improbable. Such agencies, like universities themselves, are in the end molded by public opinion. There is, however, no method by which this can be proved to one who sees in the existence of such an agency unfortunate influences upon the colleges and universities. The two opinions result from differences in the point of view, not from differences in intellectual honesty and sincerity, and such differences of view only time and experience can bring together.

It seems to me, however, that the argument that a central educational agency may exert arbitrary and unwise influence over the universities may be very fairly compared with a similar arraignment of the universities themselves which, by a somewhat singular coincidence, was put forward at a meeting of teachers simultaneously with the one just alluded to.

This complaint came from the secondary school men. They argued that the universities are outside corporations having little sympathy and knowledge of secondary school work and yet not only ready to exert over the high school an arbitrary power, but actually in a number of cases exerting this power to the harm of the secondary schools. These secondary school teachers protested most strongly against the domination of any such outside irresponsible agency.

That there is a measure of truth in this complaint no one who knows the educational situation will deny. And yet I fancy that no man is ready to advocate the abolition of universities in order to preserve the rights of the secondary schools. The real lesson, on the other hand, is that of a wise cooperation. No agency in civilized society, not even a university, can have absolute independence. What such an institution can have is freedom, to be gained however by due observance of its right relations to all other agencies in the social order. In a democracy the power of public opinion, as fast as public opinion is educated, will bring about such cooperation. The remedy for possible danger to the rights of the individual or of the single institution does not seem to lie in reducing all agencies to ineffectiveness, but rather in the general education of the whole people to an appreciation of the observance of the law. In the last analysis an educated public opinion will regulate both the relations of centralized educational agencies to the universities and the relations of the universities to the secondary schools. Meantime, no man in either form of organization will object to sincere and discriminating criticism. It is such criticism which educates public opinion.

Notwithstanding the incidental difficulties, therefore, which arise in the administration of any system of pensions, I believe that the advantages which have resulted from the conferring of pensions have far outweighed the disadvantages and that, furthermore, the advantages on the whole seem likely to become stronger with time, while the disadvantages seem likely to diminish. The value of a pension system depends not only on the intelligence and conscience of those who administer it, but on the spirit and morals of those who are to benefit by it, and the dangers of a pension system lie mainly in those universal dangers which come from human weakness and human selfishness.

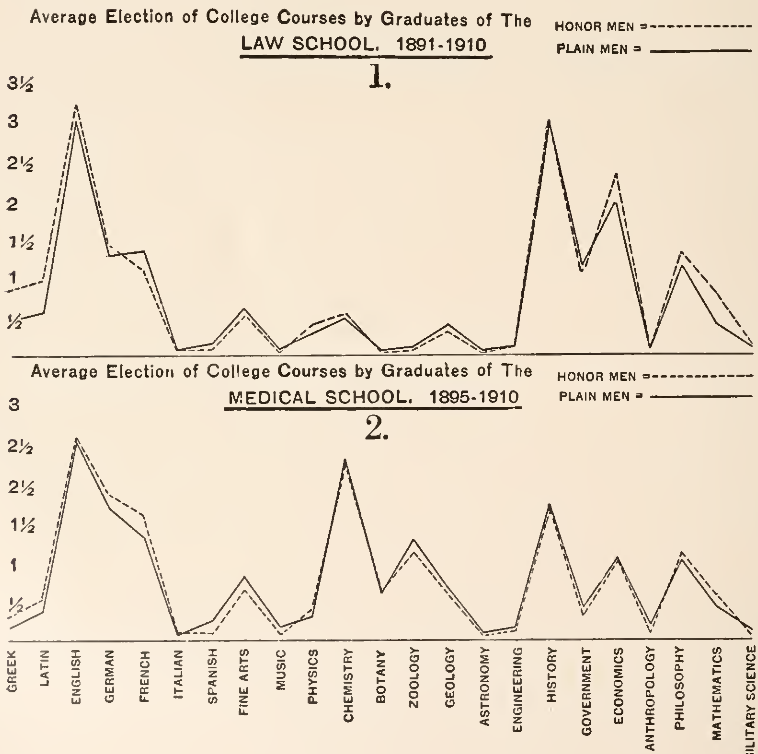
It is, to my thinking, a fair question whether the college pensions ought not, like other pensions, to carry a contributory feature. No one can be more sensible than I of the tremendous demands made upon the meager salaries of the American college teachers, and yet notwithstanding this, it is impossible to remove the college teacher from those social and moral obligations which affect all men. The experience of the world seems to point strongly to the conclusion that on the whole a contributory form of pension is likely to be most just and least harmful.

THE PROGRESS OF SCIENCE

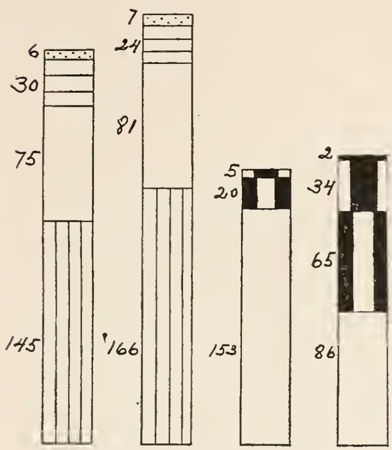
COLLEGE STUDIES AND PROFESSIONAL TRAINING

In *The Educational Review* for October, President Lowell, of Harvard University, gives some interesting statistics in regard to studies pursued in college and success in the work of the professional school. In a general way he finds that students who enter Harvard College without conditions do well in their college studies and that students who do well in college also do well in the schools of law and medicine, whereas their standing in the professional schools is not dependent on the kinds of studies pursued in college.

The diagram shows the average election of college courses by graduates of the law and medical schools, the broken lines representing the men who graduated from the professional schools with honors and the plain lines those who did not. It is apparent that the future law students took more work in history, government and economics, and the future medical students more work in the natural sciences. But the law students who in college elected more work than the average in history and political science did not do better than the others, and the medical students who elected more work than the average in



the sciences did not excel the others. On the contrary, it appears that of the 23 men who took ten or more courses in science, only 39 per cent. graduated *cum laude* from the medical school, whereas of 48 men who took less than three courses 61 per cent. graduated *cum laude*. In general, it was the case that students who elected six or more courses in any one of the four groups into which the studies at Harvard are now divided did equally well in the professional school whatever the group



The two columns on the left represent the students in the medical school who did not and who did receive honors in accordance with the subjects pursued in college. The two columns on the right represent those who did not and those who did receive honors in the medical school in accordance with their standing in college.

in which the larger share of work was done. The relations for the medical school are shown on the chart. Of 311 students who elected six or more courses in the languages in college, 145 graduated without and 166 with honors from the medical school. Of those who took six or more courses in the natural sciences, 75 graduated without and 81 with honors. Within the limits of probable error, the relations are the same for the smaller groups in political science and in philosophy and mathematics.

The two columns on the right side of the diagram show the relations between high standing in college and success in the work of the medical course. Of the 239 men who received no honors in college 36 per cent. were given honors in the medical school; of the 85 with a *cum laude* in college, 76 per cent.; of the 39 with *magna cum laude,* 87 per cent.; and the two who received *summa cum laude* received honors in the medical school.

President Lowell's theories are certainly supported by these statistics. He holds that men should be incited to obtain high grades in college and that the college course should be purely cultural without reference to the student's work in after life. He has argued that the college course should make all students equally well prepared to enter any professional school and that the entrance requirements of each professional school should be such that they are met by all students having completed a college course. Every one will of course agree that it is a good thing for students to do well in their college work, even though it may be doubted how much is gained by trying to lead students to compete with one another for honors, as President Lowell advocates. It is, however, a legitimate incentive to good work to make it known that students who do well in college, are likely also to succeed in the professional school and in after life.

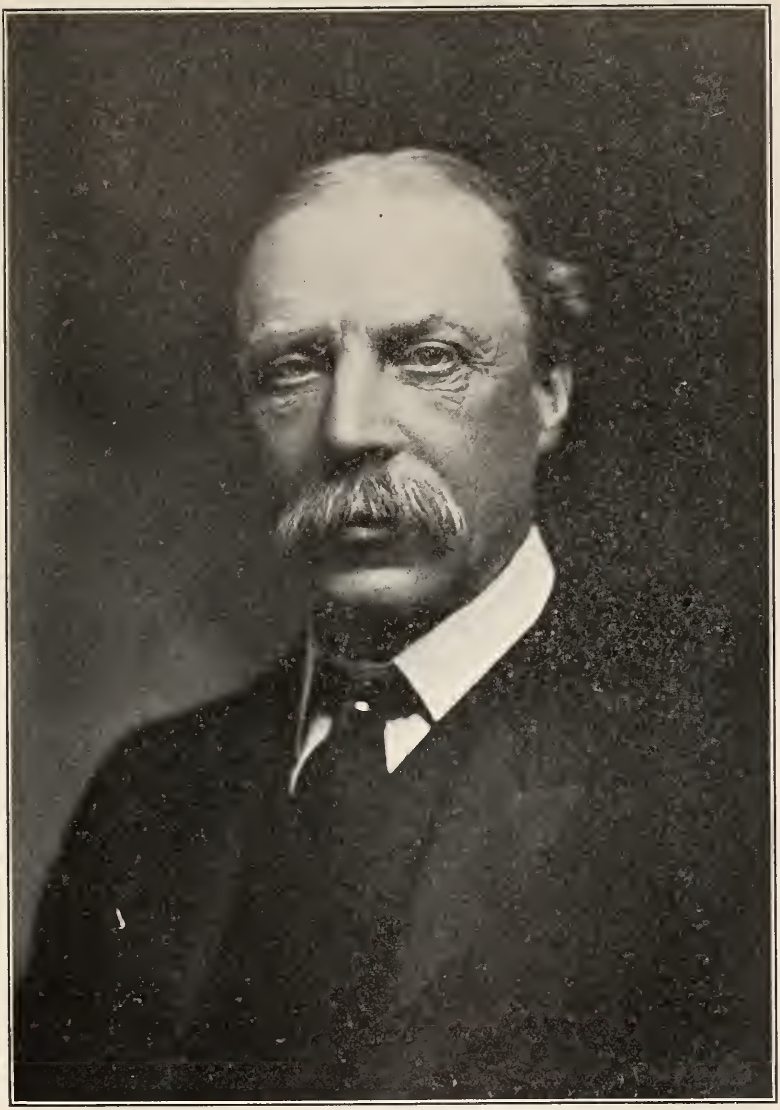
The fact that students do equally well in the medical school, whatever the studies they pursued in college, is a stronger argument for cultural studies than any theory. It is not quite convincing, as it may be argued that the courses in the natural sciences given to students at Harvard are proved by these statistics not to be the best training for the future medical student. We know that students who do well in one subject in college are likely to do well in others. This was put on a quantitative basis by Dr. Clark Wissler in a doctor's thesis from the psychological department of Columbia University, which showed that the correlation was about 0.60. The student who did well in Latin not only was likely to do well in other studies, but was as likely to do as well in mathematics or in gymnasium work as in French. Ability and hard work lead to success rather than special aptitudes or previous training. Apart from manual skill, the student can learn in four years about as much as he is able to remember, and consequently students at the end of the Harvard medical course can pass their examinations about as well whatever were their studies four to eight years before.

This does not, however, mean that a student might not have passed these examinations equally well if he had begun his medical work two years sooner and begun to practise medicine two years earlier, or that he would not have been a better prepared physician if he had left the college at the end of the sophomore year and spent six years in the work of the medical school. The real difficulty in the way of a prolonged college course in its bearing on future professional work is that the student begins too late. This is an economic danger, as only the well-to-do can enter the professions, and it is psychologically unfortunate, as by the time a man has begun his real work in life, he has passed the period when he is best able to learn how to carry it forward and most likely to have new ideas.

THE PORTSMOUTH MEETING OF THE BRITISH ASSOCIATION

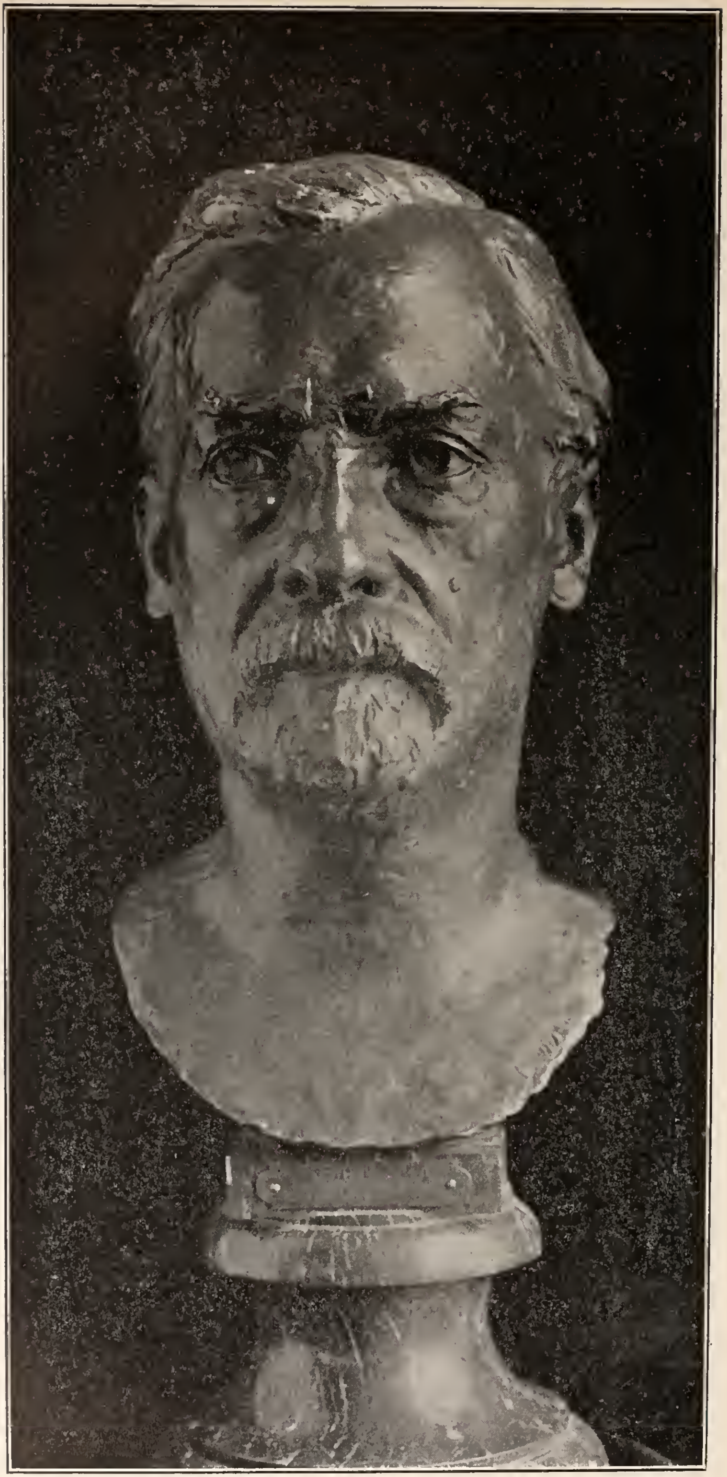
THE meeting of the British Association at Portsmouth appears to have maintained the high traditions of its eighty years of scientific service. The attendance of about 1,400 was smaller than usual, but this depends on the number of local associates who join for the meeting. Details are not at hand for Portsmouth, but at one of the larger recent meetings there were in attendance 885 members, a large part of whom were not engaged in scientific work, and in addition to these there were registered 1,384 local associates and 873 ladies. This indicates a striking difference between the meetings of the British and American associations, which has become even more emphasized in recent years. At the approaching meeting of the American Association and its affiliated societies at Washington, there will probably be about 2,500 members in attendance who will be almost exclusively scientific men. They go to attend the meetings of the special societies having very technical programs; the people of the city will know very little about the meetings and will not even attend the addresses and sessions which might be of interest to them.

The constitution of the British Association states that one of its principal objects is "to obtain a more general attention to the objects of science." The constitution of the American Association contains a similar statement. Both associations have concerned themselves with the diffusion as well as with the advancement of science, and it must be admitted that the British Association has in this direction been the more successful. It accomplishes more for the city in which it meets, and the city in turn provides social functions such as are unknown in this country. At Portsmouth there were two dukes ready to entertain the members at their castles and a bishop to preach for them on Sunday. The mayor offered both a garden party and an evening reception, and there were all sorts of social entertainments. There were excursions to the Isle of Wight and to the New Forest, and the members were taken on a battleship to witness an attack by torpedo-boat destroyers and submarines. The association in turn arranged a number of public lectures and general addresses, and these were fully reported in the daily press. Thus the London *Times* published the address of the president, Sir William Ramsay, and large parts of other addresses, together with full accounts of the proceedings. It printed in advance an elaborate forecast of the meeting and afterwards an



DR. E. A. SCHÄFER,

Professor of Physiology in the University of Edinburgh, President of the British Association for the Advancement of Science.



Bust of Pasteur.

Presented by the Pasteur Institute, Paris, to the Rockefeller Institute for Medical Research, New York.

Professor Ed. Suess,

Emeritus Professor of Geology in the University of Vienna.

extended report, devoting many pages to it. Nothing of that kind happens in America. The general organization of society here accounts for the absence of social functions which can perhaps be well spared, but it seems to be unfortunate that a democratic society does not take an active interest in the scientific work which has made possible its existence and on which it depends for its extension and permanence.

At Portsmouth, Professor E. A. Schäfer, the eminent physiologist of the University of Edinburgh, was elected to preside over the meeting to be held next year at Dundee. The association will meet the following year in Birmingham, and in 1914 or 1915 a visit is planned to Australia. The British Association has in recent years met in South Africa and in Canada, and in this way fulfils its national and imperial functions better than the American Association, which has never met further west than Denver. It may be hoped that our association will in 1915 meet on the Pacific coast and at Hawaii. It might be possible to arrange that those members who were able should proceed to Australasia to attend the meetings there, while British and Australian men of science might join our association at Hawaii and in California, with an opportunity to visit the San Francisco Exposition, which should aim to surpass the St. Louis Exposition in its scientific congresses.

A HANDBOOK OF UNIVERSITIES

Minerva, which for twenty years has been an invaluable annual for university men, has issued as a supplement a volume containing details of the organization of universities and colleges throughout the world. It is to be followed by a second volume with similar material in regard to libraries, museums, observatories, etc. A vast amount of information is packed into 623 pages, printed in type almost too small to be legible. Like the annual issue of *Minerva*, it is edited with unusual accuracy, but, as is likely to be the case, the material appears to be the more satisfactory, the less the firsthand knowledge of the reader. Thus the only lectureship referred to under American universities is the "Sethman (intended for Silliman) lecturer at Yale." The following account of our fraternities would not give a clear or correct impression to foreigners: "In the larger colleges and in the universities most students are members of one or more 'fraternities.' The members live in the college, usually together in a chapter house. The most important is the Phi Beta Kappa Fraternity, founded in 1776." It is not true that Columbia University was in 1890 "completely reorganized on the model of the German universities." There is no reason to include the Cooper Union and to exclude the West Point Military Academy. But it seems captious to point out minor inaccuracies in a book covering such a wide field. The publishers and editors should rather be congratulated on the production of a book which could not be accomplished outside Germany. The frontispiece, here reproduced, is a portrait of Dr. Ed. Suess, professor emeritus of geology of the University of Vienna, who has just celebrated his eightieth birthday and has retired from the presidency of the Vienna Academy of Sciences.

SCIENTIFIC ITEMS

We record with regret the deaths of Professor Edward Lee Hancock, professor of applied mechanics in the Worcester Polytechnic Institute; of the Rev. Mariam Balcells, professor of mathematics at Boston College, previously director of the department of solar physics at the Observatorio del Ebro, and of Mr. Edward Whymper, known for his explorations among the Alps and in the Andes.

Dr. C. Willard Hayes, chief geologist of the U. S. Geological Survey, has retired to engage in technological work in Mexico.—At the meeting of the corporation of Yale University on September 18, Sir William Osler, regius professor of medicine at Oxford, was appointed Silliman lecturer for 1912, and Dr. Joseph P. Iddings, until 1908 professor of petrology in the University of Chicago, and now engaged in geological research, was appointed lecturer for 1913.

Owing to the epidemic of cholera, the various international congresses, geographical, agricultural and tuberculosis, will not meet in Rome this autumn. They have been postponed until the spring of 1912, the exact dates not yet being determined.—By invitation of the trustees of the New York Public Library the autumn meeting of the National Academy of Sciences will be held in its new building, beginning on November 21.

Among the public bequests made by Mr. George M. Pullman was that of $1,200,000 for founding and endowing the Pullman Free School of Manual Training at Pullman, Ill. This fund has increased to more than $2,500,000. The first step toward founding the school was the purchase, in 1908, of a campus of forty acres within the limits of the town of Pullman at a cost of $100,000. Mr. Laenas Gifford Weld, until recently professor of mathematics and dean of the faculty of liberal arts in the Iowa State University, was appointed principal in May and entered upon his new duties September 1. He will visit the leading technical and trade schools in this country and in Europe before the preparation of definite plans is undertaken.

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SCIENCE AMONG THE CHINESE

By Dr. C. K. EDMUNDS

PRESIDENT OF CANTON CHRISTIAN COLLEGE

I. Introduction

(*a*) *Chinese Science a Case of Arrested Development.*—In scientific knowledge, as in nearly everything else, China presents a case of arrested development. Chinese conceptions regarding the body of man, the materials of the earth's crust, the surface forms of our globe, of its origin and process of formation, of the vast celestial universe through which it whirls, of the nature and origin of matter and of cosmogony in general, are the conceptions characteristic of western peoples before and during the middle ages. Not only so, but they are the same as were held by her own sages centuries before that period; in many cases they express the best thought of China's deep thinkers in the days of Pythagoras and perhaps prior to his time, while in others they give us the cream of Chinese philosophy as developed during the early days of the glorious Sung dynasty (A.D. 1020–1120). While of course those who have within the last few decades read the books of the west have modified their previous notions, the number of such as compared with the general people, though rapidly increasing, is still small and the purely Chinese conceptions of anatomy, physiology and medicine still consist of interacting functions of hypothetical organs, the intermixings of various vital fluids, and the subtle influence of capricious humors; chemistry is still alchemy; geography, mere guesswork; geology, vague mythology; astronomy, astrology; and exact physical science, nil. Science in China has made few advances during the last few centuries and is now but slowly responding to a new impulse from abroad in all its departments.

(*b*) *Their Inventions, Arts, Engineering, not Evidence of Scientific Attainment.*—To be sure, several striking inventions are probably to the credit of the Chinese—gunpowder, printing, mariner's compass, paper, etc., but the original crude forms or methods were not improved. Their use among the Chinese apparently had no direct effect in promoting their development among western peoples, and in nearly every case the invention was founded on the specific properties of matter discoverable directly and did not involve any scientific concept of principle established and tested by observation. It would seem too that much of the Chinese servile imitation in mechanics, metallurgy and other arts is due to ignorance of the real nature of the materials they use, and yet it is not for long that such things have been intimately known to ourselves of the west. The Chinese have made little progress in investigating the principles of mechanics, but have, however, practically understood most of the common mechanical advantages involved in various simple appliances. The lever, wheel and axle, cog wheels, wedge and rack and pinion, have long been known, but the screw is not frequent. In many of their contrivances there is an excessive expenditure of human strength; in many the object is merely to give a direction to this strength, not to decrease it, as in their manner of carrying a heavy stone, instead of constructing a simple truck that would transport it with half the expense of human power; yet the use of a truck would require something more in the way of good roads than most parts of China can boast of, and again human labor is almost the cheapest thing in China.

While it is true that the manufactures of silk, of porcelain and of lacquered-ware were original with the Chinese, and that in none of these have foreigners yet succeeded in fully equalling the native product, and while the French looms are practically the same as those in Canton, except that steam power takes the place of human feet, it is also true that the mechanical arts and implements of the Chinese have a simplicity which suggests that the faculty of invention died with the initiator.

Three accomplishments in Chinese engineering, however, challenge the rest of the world to show similar feats in any remote time. The Great Wall, traversing high mountains and large rivers, built two hundred years before the Christian era, still stands as the most extensive monument of antiquity to attest the high engineering skill and kingly energy of that day. Of like herculean proportions and for a more useful purpose is the Grand Canal which up to the date of its construction was the greatest public commercial work ever undertaken. The Great Sea Wall along the north shore of Hangchow Bay, judged in the light of the tremendous difficulties involved in its construction merits even greater praise for native energy and skill.[1] And yet the very present

[1] See "A Visit to the Hangchow Bore," THE POPULAR SCIENCE MONTHLY, February and March, 1908.

condition of the Grand Canal, which has doubtless been its condition for a century or more, is an eloquent witness to arrested development due to failure to apply hydraulic improvements.

While giving due credit for what they have done, we feel justified in concluding that the arts and the inventions of the Chinese do not, after all, witness to any degree of scientific attainment among them. Many of the later modern inventions of western people are the result of applied science, which certainly was not the case with these early inventions of the Chinese. There seems, however, to be room for a difference of opinion even among authorities. In 1839 G. T. Lay asserted in writing about Chinese musical instruments:

> It has been declared that the Chinese have no science, but of a surety, if we advance in the free and scholar-like spirit of antiquarian research, we shall be obliged to set our feet upon the head of this assertion at every step in our progress.

And yet in his authoritative work, Williams closes his rather compendious account of "Science among the Chinese" with this summary:

> On the whole it may be said that in all departments of learning the Chinese are unscientific; and that while they have collected a great variety of facts, invented many arts, and brought a few to a high degree of excellence, they have never pursued a single subject in a way calculated to lead them to a right understanding of it, or reached a proper classification of the information they possessed relating to it.

It may be of interest then to notice some of the leading ideas in what we may call "Chinese science" and to inquire into the causes of China's scientific backwardness as compared with modern western knowledge. In doing this we shall be largely indebted to Williams's "Middle Kingdom" for many of our facts and to Martin's "Lore of Cathay" for suggestive lines of thought.

II. The Content of "Chinese Science"

1. *Anatomy.*—Wylie has noted fifty-nine Chinese treaties in medicine and physiology (some of them belonging to the earliest days), many of which contain good sense and sound advice amid the strangest theories. Harland has lucidly and in detail described the Chinese ideas (apart from the gradually spreading foreign teaching) concerning the organization of the body and the functions of the chief viscera—false ideas which a very little dissection, a prohibited practise, would have banished. We shall not pause to consider these, but merely note that the most curious is perhaps their idea of the liver, which they place on the right side of the body.

> It has seven lobes; the soul resides in it; and schemes emanate from it; the gall-bladder is below and projects upward into it, and when the person is angry it ascends; courage dwells in it; hence the Chinese sometimes procure the gall-

bladder of tigers or bears, and even of men, especially notorious bandits executed for their daring crimes, and drink the bile, with the belief that it will impart courage.

Theories are numerous to account for the nourishment of the body and the functions of the viscera, and upon their harmonious connection with each other and the five metals, colors, tastes and planets is founded the well-being of the system, the whole intimately connected with the all-pervading functions of the *yin* and *yang*—those universal solvents in Chinese philosophy.

2. *Materia Medica, Botany and Zoology.*—The advance made by the Chinese themselves in the study of natural history is shown by the contents of the two chief works—"Pun Tsao," or "Herbal," compiled by Li Shi Chin after thirty years spent in collecting information, published about 1590 (40 octavo volumes—52 chapters), and "Chih Wah Ming-shih Tu-kao," or "Researches into the Names and Virtues of Plants," 60 volumes with plates, some of them good drawings, published in 1848.

The author of the first of these treatises was the first and last purely native critical writer on natural science. He consulted some eight hundred previous authors and selected fifteen hundred and eighteen prescriptions, to which he added three hundred and seventy-four new ones, arranging the whole in what for his day was a scientific manner.

After two introductory chapters on the practise of medicine and an index to the recipes contained in the work, which fills the first seven volumes, there are two chapters (filling three and a half volumes), giving a list of medicines for the cure of all diseases, and this with an essay on the pulse in the final volume constitutes the therapeutical section of the treatise. The remaining forty-eight chapters cover, after the fashion of the author, the whole range of natural objects—treating of inorganic substances under "water" and "fire" and minerals, as earth, metals, gems and stones, throwing into a polyglot chapter what could not be included in the preceding sections; the vegetable kingdom is presented under the five divisions—herbs, grains, vegetables, fruits and trees; these again into families containing members which have no real relationship to each other, the lowest term sometimes being a genus, a species, or even a variety, as Linnæus used these terms.

In the classification of the minerals, etc., the influence of the language itself is shown, for, as pointed out by Williams, the division is exactly that of the seven radicals which stand for fire, water, earth, metals, gems, stones and salts, under which the names of inorganic substances were classified in the imperial dictionary. The same thing is true for other parts of the treatise.

In classifying herbs, the habitat is taken as the criterion, an "herb" denoting whatever is not eaten or used in the arts or which does not attain to the magnitude of a tree.

The zoological grouping is as crude and unscientific as that of plants, though the sixteen zoological characters in the language are not so far astray from being true types of classes as the eleven botanical ones, and these groups, though containing many anomalies, are still sufficiently natural to teach those who write the language something of the world around them.

The properties of the objects spoken of are discussed in a very methodical manner, so that a student can immediately turn to a plant or mineral and ascertain its virtues.

3. *Geography.*—A few sentences from Williams's "Middle Kingdom" will show the state of geographical knowledge among the Chinese prior to western influence.

> Their geographical knowledge is ridiculous. Maps of their own territories are tolerably good, being originally drawn from actual surveys made by nine of the Jesuits, between 1708 and 1718, and since that time have been filled up and changed to conform to alterations and divisions. Before the day of western influence, and even long after, to a great extent until the present decade, in fact, the Chinese did not teach geography in their schools, even of their own empire. The common people have no knowledge, therefore, of the form and divisions of the globe, and the size and position of the kingdoms of the earth. Their common maps delineate them very erroneously, scattering islands, kingdoms and continents, as they have heard of their existence at haphazard and in various corners beyond the frontiers. . . . Their notions of the earth's inhabitants are equally whimsical. . . . Charts for the guidance of the navigator, or instruments to aid him in determining his position at sea, the Chinese are nearly or quite destitute of; they have retrograded rather than progressed in navigation, if one judges from the accounts of their former trade with ports in the Persian Gulf, on the Malabar coast, and in the Archipelago.

Of course in the modern schools now under way throughout the empire correct geographical notions are being taught; but such schools have been so few up till 1900 and the total number of modern students so small even since then, that the notions of the common people are still subject to Williams's characterization. To what extent even the supposedly more intelligent are still "at sea" in such matters is well shown by two recent cases, which illustrate also some effects of present-day scientific ideas upon Chinese minds educated according to the methods which have prevailed in China for ages.

At the Shansi University, in discussing the search for the North Pole, a holder of the Chinese first degree seriously suggested that when the ship had proceeded as far north as possible, the pole might be seen with the aid of a telescope. Another man thought of the same expedient, but considered that the curvature of the earth would render it impossible, and suggested that ascending in a balloon might afford the opportunity to use the telescope to see the pole. Still another man thought it would be simpler first to moderate the climate of the polar regions by planting trees along the way there, and by diverting the gulf stream in that direction to render possible a closer approach to the Pole.

Another graduate of the ancient system in Canton offered the following as an explanation of why he thought it was hotter in Peking than in Canton:

"At Peking the earth is thicker than at Canton, and so a person living on top of the earth is nearer the sun at Peking than at Canton and hence gets more heat, and we know that the earth is thicker at Peking than at Canton because in Peking you have to dig many tens of feet to get water, whereas in Canton you can readily strike water at ten to twenty feet."

4. *Astronomy—Astrology.*—The precise attainments of the ancient Chinese in astronomy are not easily understood from the scanty records. To the burning of all native scientific books, except those on agriculture, medicine and astrology, by imperial order in 221 B.C., the Chinese attribute the loss of a mass of astronomical learning. Wylie furnishes a list of 925 solar and 574 lunar eclipses, extracted from Chinese works, observed between 2150 B.C and A.D. 1785. The earliest known record of an eclipse occurs, though imperfectly, in the ancient "Shu-King," or "Book of History." Retrospective calculation shows that it may have occurred as early as the autumn of 2158 B.C. Simple methods for predicting solar eclipses seem to have been in use in China before 2000 B.C., but this eclipse of 2158 B.C. is said to have appeared unexpectedly and to have so disturbed the emperor that he at once executed the two court astronomers for failing to predict it!

In the Chinese canonical books thirty-eight solar eclipses are mentioned, eighteen of which agree with modern lists, but the others seem in error in either month or year, though the day is always correct. This suggests that the records are reliable and that the non-agreement is probably due to an imperfect knowledge of the ancient calendar, particularly with reference to intercalation and the beginning of the year, which are probably irregular. Intercalations were probably introduced by Yao about 2637 B.C., but it is hardly likely that they have continued without variation to this day. Romish missionaries rectified the calendar about 1700 and have aided in its preparation until recently. A cycle of sixty years was adopted in very early times, but there is no record of when or why this number was selected. The Chinese year is lunar, but its commencement is regulated by the sun. New Year falls on the first new moon after the sun enters Aquarius, which makes it come not before January 21 nor after February 19.

Comets, whose brilliancy enabled them to be seen, have been carefully noted by the Chinese, because their course among the stars is thought to determine their influence as portents. A list of 373 comets mentioned in Chinese records has been published, extending from 611

B.C. to A.D 1621. The general value of these records is thought to entitle them to credence.

While these observations of eclipses and comets were made for astrological and state purposes, they are not without value to European astronomers and chronologists. It would not be entirely safe to judge of the astronomical attainments of the Chinese from what has come down to our day, or by present popular notions. The knowledge contained in their own scientific books has not been taught, and in general the astronomical ideas of the Chinese are vague and inaccurate and serve as the basis of superstitious astrology rather than as an agency of enlightenment among the people. The writer vividly recalls his experience during a recent lunar eclipse, when almost the entire population of one of the largest cities on the Yangtsze turned out, each one carrying something with which to make a noise, kettles, pans, sticks, drums, gongs, fire-crackers, etc., to aid in frightening away the dragon of the sky from his hideous feast. And even the crew of a Chinese man-of-war, foreign built and armed with Krupp guns, will by orders published in *The Peking Gazette* turn out with drums, iron pans, etc., to make a din to "save the moon.'

Chinese astronomers distinguished five planets, or "moving stars," and named them according to their ideas of elementary substances: Venus, Golden; Jupiter, Wooden; Mercury, Water; Mars, Fire; Saturn, Soil. To them the galaxy was The Heavenly River, a close analogy to our term, The Milky Way. It is interesting to note how descriptive the Chinese terms are as applied in translations of modern astronomical ideas—a nebula is a "star-mist"; asteroids are "small moving stars"; the spectroscope is the "shooting shadow-lamp"; and spectrum analysis is "the shooting-shadow-difference-telling-light-method."

5. *Mathematics.*—The arithmetical notation of the Chinese is based on the decimal principle, but as their figures are not changed in value by position, it is difficult to write out clearly the several steps in solving a problem. Arithmetical calculations are performed with a "counting board," an arrangement of balls on wires, which can, however, only serve as an index for the progress and result of a calculation done in the head, so that if an error is made, the whole operation must be done again.

The study of arithmetic has attracted attention among the Chinese from early times, and notices found in historical works indicate some treaties extant even in the Han dynasty (206 B.C–A.D. 214), followed by a great number of general and particular works down to the Sung Dynasty (1020–1120 A.D.). The Hindu processes in algebra were known to Chinese mathematicians, but though studied even after intercourse between the countries had ceased, these branches made slow progress down to the end of the Ming Dynasty (A.D. 1368–1644).

The mathematical writings of the early Romist missionaries greatly improved the mathematical texts available in Chinese, and since foreigners have begun to introduce western science, the development has been rapid. But aside from the graduates from modern schools, the knowledge of mathematics even among the learned men of China is very small, and the common people study it only as far as their business requires, and that is exceedingly little. The cumbersome notation and the little aid which such studies gave in the ancient system of literary examinations (only abolished in 1905) doubtless discouraged the pursuit of what they seem to have no taste for as a people. Chinese authors acknowledge the superiority of western mathematicians, and generally ascribe their advance in the exact sciences to this power.

6. *Action and Reaction of Elements.*—Williams in his "Middle Kingdom" gives a table showing the leading "elementary" correspondencies in the curious speculations used by Chinese philosophers to account for any possible contingency in the changes of the visible universe, which in the hands of geomancers and fortune-tellers are the bases of considerable imposition on the people. The five elementary powers or *hing* are: water, fire, wood, metal and earth, and the table gives the qualities, tastes, and activities of the five *hing* as correlated with five points of the compass (the fifth being "center"), the five corresponding planets, five colors, five viscera, five musical notes, five early emperors, four seasons, and four quarters of the zodiac. But to consider these ideas in detail would lead too far afield into unprofitable vagaries.

7. *Chemistry—Alchemy.*—Chemistry and metallurgy have been unknown as sciences, but many operations in them are performed with a considerable degree of success, and bear testimony to Chinese shrewdness and ingenuity in the existing state of their knowledge. The skill which they exhibit in metallurgy, their brilliant dye-stuffs and numerous pigments; their early knowledge of gunpowder, alcohol, arsenic, Glauber's salt, calomel and corrosive sublimate; their pyrotechny; their asphyxiating and anesthetic compounds—all give evidence of no contemptible proficiency in practical chemistry. In their books of curious recipes (see section 2) are instructions for the manufacture of sympathetic inks, for removing stains, alloying metals, counterfeiting gold, whitening copper, overlaying the baser with the precious metals, etc., many of the rules in which are still in common use, and bear in their very terms the stamp of an alchemic origin. Dr. Martin in his "Lore of Cathay" presents striking evidence to show that in all probability western alchemy, from which our modern chemistry has come, had its root in the art as practised in China, where it appeared as an indigenous product, coeval with the dawn of letters.

One doctrine of Taoism which was developed six centuries before Christ regards the soul and body as identical in substance, and maintains the possibility of preventing their dissolution by a course of physical discipline—a seed-thought which led the disciples of Laotze to investigate the specific properties of matter in the two-fold search for long life and riches. In studying both the vegetable and mineral kingdoms Chinese alchemists were guided by the supposed analogy of man to material nature, which led them to ascribe an essence or spirit not only to animals and plants, but to minerals as well, so that in their view matter itself was constantly passing the limits of sense and assuming the character of conscious spirit. Thus was the world filled with fairies and genii.

We need not discuss in detail the characteristic ideas of Chinese alchemy, but merely note that it had full vigor six centuries prior to western alchemy, which did not appear till A.D. 400 when intercourse was quite frequent between China and Byzantium, Alexandria and Bagdad. The two schools had much in common: same aims, closely corresponding properties ascribed to the two elixirs in each; principles, means, mystical character of nomenclature, and extravagant style of alchemic writings, all practically identical. So that, although it may be granted that the leading objects of alchemical pursuit might have occurred to men in any country as they felt their way towards a knowledge of nature, yet an independent origin seems unlikely, and it is almost certain that alchemy had its birth in the far east, yea in China, since the claims of India seem excluded by the abundant proof that the alchemy of China is not an exotic, but an indigenous product, the earliest forms of which are found in the "Book of Changes," a significant title, whose diagrams date back to 2800 B.C., the text to 1150 B.C., and the Confucian commentary thereon to 500 B.C. It is a striking fact that this book, chief in the canon of Taoism, was spared from the flames of the Tyrant of Ch'in to which all other writings of Confucius and his disciples were consigned.

8. *General Cosmological Ideas.*—Contrast the modern ideas of the age and origin of the earth and of the extent of the universe in time with the following conceptions of Chu Hi (Chu Fu Tsz), the most famous of the eleventh-century philosophers:

> In the beginning heaven and earth were just the light and a dark air. This one air revolved, grinding around and around. When it ground quickly much sediment was compressed, which, having no means of exit, coagulated and formed the earth in the center. The subtle portion of the air then became heaven and the sun, moon and stars, which unceasingly revolve on the outside. The earth is in the center; it is not below the center.
>
> Heaven revolving without ceasing, day and night also revolve, and hence the earth is exactly in the center. If heaven should stand still for one moment, then the earth must fall down; but heaven revolves quickly, and hence much sediment is coagulated in the center. The earth is in the sediment of the air; and hence it is said, the light, pure air became heaven, the heavy, muddy air became earth.

At the beginning of heaven and earth, before chaos was divided, I think there were only two things—fire and water—and the sediment of the water formed the earth. When one ascends a height and looks down, the crowd of hills resemble the waves of the sea in appearance; the water just flowed like this. I know not at what period it coagulated. At first it was very soft, but afterward coagulated and became hard. One asked whether it resembled sand thrown up by the tide? He replied, just so; the coarsest sediment of the water became earth and the purest portion of the fire became wind, thunder, lightning, sun and stars. . . . Before chaos was divided the *Yin-yang*, or light-dark, air was mixed up and dark, and when it divided the center formed an enormous and most brilliant opening, and the two principles were established. Shao Kang-tsieh considers one hundred and twenty-nine thousand six hundred years to be a *yuen*, or *kalpa;* then, before this period of one hundred and twenty-nine thousand six hundred years there was another opening and spreading out of the world; and before that again there was another like the present; so that motion and rest, light and darkness, have no beginning. . . .

There is nothing outside heaven and earth, and hence their form has limits, while their air has no limit. Because the air is extremely condensed, therefore it can support the earth; if it were not so, the earth would fall down.

Chu Hi's theory considers the world to be a plane surface—straight, square and large—measuring each way about 1,500 miles and bounded on the four sides by the four seas. The sun, moon and stars revolve around it at the uniform distance of 4,000 miles. Estimates of the long mythological periods antecedent to the appearance of Fuh-hi (the monarch of "highest antiquity," 2852 B.C., according to Chinese annals) vary from 45,000 to 500,000 years.

These ancient Chinese writings are a curious mixture of sense and nonsense, partially laying the foundation of a just argument and ending with a tremendous non-sequitur, apparently satisfactory to themselves, but showing pretty conclusively how little pains they took to gather facts and discuss their bearings. One thing is to be observed concerning them, which is characteristic to-day, viz., there is no hierarchy of gods brought in to rule and inhabit the world they made; no transfer of human love and hate, passions and hopes, to the powers above, as in the Greek or Egyptian mythology; all here is represented as moving on in quiet order, the work of disembodied agencies or principles. "There is no religion, no imagination; all is impassible, passionless, uninteresting."

Perhaps the most sensible and orderly account of the creation to be found in these writings is the following:

Heaven was formless, an utter chaos; the whole mass was nothing but confusion. Order was first produced in the pure ether, and out of it the universe came forth; the universe produced air and the air the milky way. When the pure male principle *yang* had been diluted, it formed the heavens; the heavy and thick parts coagulated and formed the earth. The refined particles united very soon, but the union of the thick and heavy went on slowly; therefore the heavens came into existence first and the earth afterward. From the subtle essence of heaven and earth the dual principles *yin* and *yang* were formed; from their joint operation came the four seasons, and these putting forth their energies gave birth to all; they produced fire; and the finest parts of the fire formed the sun. The cold exhalations of the *yin* being likewise condensed, produced water; and the finest parts of the watery substance formed the moon. By the seminal influence of the sun and moon came the stars. Thus heaven was adorned with sun, moon and stars; the earth also received rain, rivers and dust.

But such explanations were too subtle for the common people, and they personified and deified the powers and operations, though with far less imaginative genius and fine taste than the Greeks displayed in the same line. The most striking legend is that of *Pwanku,* the first creature, who was "hatched" from chaos by the dual powers and who then chiseled the universe into form and order by the might of his hands. His efforts continued 18,000 years, and by degrees he and his handiwork increased:

The heavens rose, the earth spread out and thickened, and *Pwanku* grew in stature, six feet every day, till, his labors done, he died for the benefit of his handiwork. His head became mountains, his breath wind and clouds, and his voice thunder; his limbs were changed into the four poles, his veins into rivers, his sinews into the undulations of the earth's surface, and his flesh into fields; his beard, like Bernice's hair, was turned into stars, his skin and hair into herbs and trees, and his teeth, bones, and marrow into metals, rocks, and precious stones; his dropping sweat increased to rain, and lastly, the insects which stuck to his body were transformed into people!

It must be confessed that most of us will find this quite as clear and a far more interesting account of the universe than the learned disquisition of the famous Chu Fu Tsz.

(*To be concluded*)

WHY DO CERTAIN LIVING FORMS PRODUCE LIGHT?

By F. ALEX. McDERMOTT

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TO every observer of natural phenomena, the query must some time come, "Why do certain living creatures produce light?" The luminous molds of decaying wood, the photogenic bacteria of the sea-water, the fire-flies and lightning bugs, the deep-sea fish and other mysterious forms "that move in the waters"—why should some of them be endowed with the property of producing light? The question is undoubtedly one of fundamental biologic importance. The production of light by living forms is really no more wonderful than the production of heat, motion or electricity, but the production of heat and of motion is so common and so well known that but little attention is paid to them, while the forms which produce electricity are relatively so scarce that they are little known outside of the scientific world. Between these classes are the forms possessing the photogenic function—sufficiently common to be well known almost everywhere, and yet sufficiently scattered among the creatures of the earth to excite wonder and admiration at the novelty of the property. We can, of course, beg the question by replying, "These creatures have the power of producing within themselves some chemical substance which, under certain circumstances, produces light, probably as the result of oxidation," but this or equivalent statements leave us very little nearer satisfaction than at first.

The matter presents also another question which is difficult to answer: Why should one creature be endowed with the photogenic function, and yet some other form, closely related to the first, be unprovided therewith? Did all creatures originally possess the power to produce light and have all but the few we know lost this power, or have the few that possess photogenicity acquired the power as a result of the development of certain habits or conditions of life? It seems probable that both explanations may be advanced for different forms—*i. e.*, that in some cases related existing forms, some of which possess the photogenic function and others of which do not, are descended from a common photogenic ancestor, while in others the function has been developed during the history of the species.

There are certainly three reasons for the existence of the photogenie function some one of which is applicable to the great majority of luminous creatures above the unicellular and very lowly organized forms. The first of these is that it is a secondary sexual character; the second, it is protective in purpose; third, it is a lure for prey. Other less general or less obvious uses may be shown, but in the great majority of cases one or the other of these explanations of the use of the light-producing function will be found adequate, and sometimes more than one will apply to a given species.

The simplest luminous forms are the bacteria. It is certainly difficult to see that photogenicity can be of any especial service to these unicellular organisms. Most, if not all, of the photogenic bacteria are of marine origin, and it is possible that some of them may be pathogenic to certain marine creatures when ingested, and the light thus serves to warn the bacterivorous plankton, etc., that these bacteria are dangerous food. Some species have been found to be pathogenic to Talitrus, a crustacean, which may serve as a case in point.

Luminous fungi are quite common, and here again we must leave the question with at most only a poor attempt at explanation. Protective or warning it may be; but the author has never heard of luminosity in the most poisonous of all fungi, the Amanitas, and certainly the luminous fungi he has seen did not appear to form any exception to the usual fate of fungi in general of being abundantly attacked by various species of insects.

In both of these cases, the photogenicity may be like the fluorescence of extracts of the common firefly, *Photinus pyralis,* and of cultures of *Bacillus fluorescens liquefaciens*—merely a property of some chemical substance elaborated by the life processes of the organism, and having no bearing upon its economy.

In simple marine forms like *Noctiluca miliaris,* the *Pyrocystæ, Pyrosoma,* etc., it is possible, though unlikely, that the luminosity has a warning significance and it is obviously not a sexual character. These creatures exist in swarms, or in the form of communities—compound, or rather composite animals—and it would appear very probable that in them the possession of the power to produce light finds its usefulness in the fact that by its means they are enabled to communicate in such ways as their low state of organization may require.

It is perhaps a digression, but a few words may not be amiss as to why the emission of light would be more useful to marine creatures than some other modes of communication in use among land forms. The sea-water is full of currents, ever changing and wavering; it varies in density slightly in different portions, owing to slight variation in concentration and in temperature. Therefore, the emission of a substance to produce olfactory or gustatory sensations would be of little use as a means of communication, especially to a creature capable of motion, as many luminous forms are; they would have far more control over their own movements than over that of any emission. The production of a sound would be better so far as transmission is concerned, for water is an excellent transmitter of sound; but to produce a sound, especially under water, a not inconsiderable amount of power is required—as may easily be demonstrated by trying to clap one's hands under water—and this amount of power is far and away beyond any possessed by the luminous marine creatures. True, some fish emit sounds—*e. g.*, the drum-fish—but those marine creatures which do so are of considerable power and a quite high degree of organization. All living creatures, probably without exception, produce a certain amount of heat through their life-processes; but heat is obviously of no value so far as the purposes of communication are concerned, especially in an immense body of liquid of high specific heat. Variations in pressure more especially vibrations of longer interval than those of sound, may, of course, be produced and transmitted very effectively, but here again much power is required. As a matter of fact, some species of fishes have been found to possess along their lateral line, organs susceptible to vibration-frequencies approaching six per second in the water. Electricity is a possibility, but in all cases of electrical tissues so far studied, considerable masses of muscular tissue have been found as the site of the electrogenic phenomena, again a matter out of the question for a simple organism. With light the problem is different: All that is necessary is the elaboration by the cell through its vital processes of a substance which, when in contact with the oxygen dissolved in the sea-water, will produce light. Since certain bacteria can produce such a material from a compound as comparatively simple as asparagin (amino-succinamidic acid, $CONH_2 \cdot CHNH_2 \cdot CH_2 \cdot CO_2H$), this is a matter of comparative ease and requiring nothing more than the metabolic processes which might be ordinarily expected. After synthesis, the substance when brought into contact with the sea-water would be oxidized with the evolution of light. Light knows little of water currents, and but little more of differences in concentration; it would spread in all directions from the point of emission, and to the delicate structures of the ocean fauna and flora, would, however weak it might appear to human eyes, be sensible for considerable distances. Hence light is an ideal method of communication for marine forms of low organization and indeed for many of those of higher organization.

Returning again to a discussion of the various forms: Perhaps the first case, in the upward scale, where we may apply with any degree of certainty one of the uses mentioned before, is that of certain marine worms, the Annelids. Professor W. T. Galloway has recently shown the use of photogenicity in a species of Odontosyllid as a mating adaptation, with evidence which leaves little ground for doubt. In this case propagation of the species appears to be entirely dependent upon a periodic photogenicity limited to certain more or less definite portions of the year, of the month, and of certain hours of the early evening, during which the male is attracted from below to the luminous female at the surface. Various species of earth worms have also been reported to be photogenic, and it seems probable that the usefulness of the luminosity in this case is somewhat the same as in the Odontosyllid mentioned above.

The bivalve *Pholas dactylus* presents another anomaly, however, for it lives a rather sedentary life, and is certainly not poisonous, at least to man. Yet it possesses definite photogenic organs. Although it is possible that in this case the luminosity is protective, we probably have here one of the cases of the limited use of photogenicity, not yet discovered.

Among the Crustacea there are several interesting cases of photogenicity, and in regard to them, and indeed to the whole subject of the use of "phosphorescence" in sea-forms, Alcock's interesting book "A Naturalist in Indian Seas," is well worth reading. Certain shrimp-like crustaceans throw out from glands, corresponding to kidneys, a substance which in contact with sea-water produces clouds of bluish light. There seems but little doubt that this is defensive in nature, and acts in much the same manner as the "ink" of the cuttle-fish. Some of these prawns are provided with enormous eyes, others with only rudimentary ones, and some with none at all. Alcock also mentions a large spider-crab, which, although completely blind, "shone like a star." Here we may readily conceive the light is alluring in function, serving to attract the creatures on which the crab feeds.

Among the insects we find the most widely known cases of photogenicity, and probably, also, the greatest field of usefulness. With the true fireflies, the Lampyridæ, the evidence that has been collected tends to show that the possession of the photogenic function is primarily a secondary sexual character. It has long been known that if the female of the European glowworm (*Lampyris noctiluca*) were exposed by night, a male would shortly come to it. The use of the photogenic function as a secondary sexual character has also been shown for the Italian luciola, and for certain of the fireflies common in the eastern United States (*e. g., Photinus pyralis*), and it appears probable that the same thing applies to the entire family. Curiously enough, the true "lightning bugs" show but little tendency to come to ordinary lights, though in *Photinus pyralis* either sex will respond to a small electric bulb operated in imitation of the light of the opposite sex.[1]

Among the Pyrophores, the Elaterid fireflies of the tropics, such as the cucuyo of Cuba, the luminosity very probably plays the same rôle as in the Lampyrids. These insects give a light which is continuous, though of varying intensity, instead of a flashing light as is emitted by

[1] McDermott, *Canad. Entomol.*, 1911 (in press).

the Lampyrids generally, and it is of interest to note that they may be attracted by an ordinary light.

To be sure, a great many insects which are not luminous themselves are attracted to light, and there is some evidence that this is something which the insects themselves can not help. The phenomenon of attraction to light among luminous insects, however, must be regarded as of particular interest, and as being most probably voluntary.

That the photogenic function in insects may also be protective or warning in significance may scarcely be doubted. The Lampyridæ, as a group, are soft, easily crushed insects, slow of motion, and often, in the females, apterous, or of but slow and labored flight. It has indeed been observed that the flash of these insects has a tendency to discourage pursuers, perhaps frightening them in some cases, but probably more often warning them that the light-bearer is inedible. The elaters are better protected by their hard, external chitin, than the soft-bodied Lampyrids, and hence it is unlikely that their luminosity has much protective purpose. So far as its possible use as a lure for prey is concerned, this is out of the question for the elaters, and also for many of the adult winged forms of the Lampyrids; the larvæ and probably some of the larviform females of Lampyrids, however, are carnivorous, and in them it is possible, though hardly probable, that the alluring significance for the photogenic function may hold good.

A few species of myriapods are known to be luminous; perhaps more species than are now known to possess this function actually possess it for short periods during the year, probably during the height of the mating season. In some myriapods, the luminosity seems to be developed in a secretion which is ejected from pre-anal glands, while in others it is located in organs on the body of the creature, as in the insects. Mrs. Thomas has shown the almost undoubted defensive character of the first class of luminosity in myriapods, while the observations of Bruner suggest rather the sexual significance in the second class.

Among the Cephalopods we find a very peculiar class of luminous organs, occurring immediately upon or just beside the eyeball, which in these creatures is often relatively enormous. Here the significance of the luminosity seems to be interpreted by the situation of the organs as an adjunct to the function of sight, and such it very probably is. But very similar organs are found on various other portions of the body and in situations where they can not very greatly aid in vision, or illuminate the creature's path through the water. Much the same thing is true of some fish, which possess one or more large photogenic organs situated near the eye, and rows of smaller organs along the sides or abdomen; here the organs near the eye are naturally considered as an aid to vision, while the others can not possibly be so considered. In both fish and cuttlefish the explanation of these body-organs is probably the same. In the depths of the sea colors are practically indistinguishable. The dim light of the stationary photogenic forms there would be insufficient to differentiate colors. But in the more than semi-darkness of these depths, a creature with a row of luminous dots along its sides would show up like an electric sign in a dark street. The arrangement of the light-giving spots could very easily be followed, even for considerable distances through the water. It is probable, therefore, that these rows of photogenic organs on the bodies of these creatures serve the purpose of plumage and pigmentation on land, a welcome for friend and a warning for foe. No doubt one species of fish, seeing a luminous streak some distance away through the water, could readily tell whether its pattern of light—its "electric sign"—spelled the same as those upon its own body, or the legend of a foe. Many of the fish that possess these rows of luminous organs, while insignificant in size, are obviously raptatorial, and are armed with vicious teeth.

Of course another expression of the luminosity of deep-sea as well as surface fish is that it is alluring. This is especially true in those species which are provided with luminous barbels, or baits, like those of the angler-fishes. Alcock mentions a blind angler-fish with a luminous barbel, in which the alluring significance is scarcely to be doubted.

An objection which seems to have been urged against the "pattern" theory of photogenicity in marine forms is that different specimens of the same species occasionally show variations in the number and distribution of their lights. It seems probable, however, that the reason for this variation may be the age of the specimens of the fish in question, the number or position of the spots varying with age. Almost any of the various books and papers on the deep-sea fish will illustrate the effect of this "pattern" arrangement as seen, for example, in *Cyclothone* and *Astronesthes*.

Still another type of organ of light-production among fishes is illustrated in Carl Chun's book "Aus den Tiefen des Weltmeeres"; in this case the luminous apparatus is set in a pit in the foremost part of the head, before the eyes. Here there can be little doubt, again, that the usefulness to the animal consists in the illumination of the "road ahead," as the searchlight does for the automobile.

A large number of other forms might be mentioned, which emit light in more or less characteristic ways, but what has gone before will serve to illustrate the majority of the points in interest. Some considerations as to the phenomenon in the fireflies may, however, be of interest, especially as deductions therefrom will doubtless hold true for many other luminous forms also.

It has been observed that the various species of fireflies (Lampyrids) emit lights of slightly differing tone, and in decidedly different manners. For instance, the observer would soon notice that the lights of *Photinus pyralis* and *Photinus scintillans* were decidedly more yellowish than those of *Photuris pennsylvanica* and *Lecontea lucifera*, and that the latter were distinctly greenish in tone. A little further observation would soon enable one to distinguish these two latter insects from the two former ones also through the different method of light-emission; the flickering flashes usually given by *Photuris* and *Lecontea* differing markedly from the long flash of the *Photini*. Thus it becomes probable that different species can recognize their own kind through the color and manner of emission of the light.

Another interesting circumstance is that the majority of Lampyrids have their luminous apparatus on the ventral side, the greater part of the light being directed downwards and sideways, and but very little passing upward. The effect of this ventral arrangement so far as the sexes is concerned is that a female resting on a leaf or on the ground illuminates by her flash a considerable portion of the supporting surface, and a male flying above her would see not merely a flash, but a silhouette of his mate against an illuminated background. The green color of the light would, of course, be of special advantage on foliage. Moreover, the flash of the flying male would illuminate most particularly an area immediately below him and ahead of him, as these insects fly with the body inclined, the head being highest. In species where the male is non-luminous, or but slightly so, this last service does not exist, while in those like *Photuris*, where both sexes are about equally active, the manner of applying the luminous property may be entirely different; it is perhaps significant in this latter group, that the light is easily visible from the dorsal side between the elytra. The cucuyo (*Pyrophorus noctilucus*) in which both sexes are equally active, have lights both above and below.

We have been considering the purpose of biophotogenicity so far as its application to the creatures possessing the function is concerned, and to a more limited extent, to their enemies. A few words may well be given regarding its relation to man. The use of the cucuyos as decorations and as night-lamps in the tropical countries is quite well known, and a number of instances have been recorded where travelers have owed their safe passage and even their lives to the light given by a collection of these Elaterid beetles. Several naturalists have written and read by the light of vessels filled with *Noctiluca* and other sea-organisms, and Chun has photographed a Cephalopod by means of its own light. The luminous bacteria have been put to a number of uses, mainly in the laboratory; flasks coated on the interior with fresh cultures of some of these organisms give light which appears of considerable intensity when the eye becomes accustomed to it, and Dubois and Molisch have taken quite a number of photographs by bacterial light. It has been suggested that "living lamps" made from these bacteria could be used to advantage in coal mines and powder magazines, since as they emit no appreciable heat, they would be absolutely without danger of producing an explosion. They would certainly furnish a nice cool light for use in summer; the author would very much like to have one here in his little study now, in place of the Welsbach which is engaged in turning some 98 per cent. of its expended energy into heat instead of light, after a day that has shown 90° F. However, such lamps would probably not do for anything like general illumination, even if the intensity were great enough, for in their light any color effects beyond a very limited range would be impossible. Color considerations would not be a considerable factor in mines and mills, however, so this does not interfere with this application.

It is more reasonable, however, to consider that these luminous forms merely point to what is possible in the way of efficient light—to serve as the goal to which all effort in the improvement of light-efficiency must strive. This must be the ideal—light without heat.

THE WATER RELATIONS OF DESERT PLANTS

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WHILE working as a student in the laboratory of Professor O. P. Jenkins at DePauw University twenty-three years ago, a typewritten schedule of experiments in plant physiology by Professor J. C. Arthur was placed in my hands as a guide in some practical work that was to extend throughout the collegiate year. The program in question probably constituted the first attempt of its kind in an American school, and its series of demonstrations may be taken to represent with fair accuracy the concepts and assumptions which might be safely presented to a student at that time.

Sachs and his students had made contributions of immense importance in growth, organogeny, irritability and tropisms in general, but the first serious efforts at analysis of the physical phenomena underlying the action of organisms may be assigned to Pfeffer and DeVries. Pfeffer established the principles of osmosis by a study of the behavior of crystalloidal substances toward membranes, the results of which were published in 1877, and in the same year DeVries brought out his contributions on turgidity. To the latter we owe the first systematic analysis of turgor, and of the mechanism by which the rigidity and firmness of soft-bodied organisms are maintained and by which movements are executed. The plasmolytic method for the detection of the differential action of substances and membranes, and the establishment of the principle of isotonic coefficients were also the work of DeVries. Both of these authors were intent on finding the solution of problems in plant physiology, in which they were notably successful, but their results form the basis of the dissociation theory of Arrhenius, and theory of pressure in solutions of van't Hoff, which together may be regarded as the basis of modern physics and chemistry.

It seems highly characteristic of research in plant physiology that devotion to many of its problems may lead the student far afield from botany, or the stricter domain of biology. The worker in this subject frequently finds it necessary to build cantilever bridges across chasms which yawn in front of him to find that the farther ends of his spans comes down to the solid ground of chemistry, physics, climatology or geology. At present, however, he has come upon rifts which he can not cross without aid from the farther side.

The conclusions of DeVries and Pfeffer, impressive as to their inclusiveness and with some of their applications ranging far ahead of the science of the time-yielded methods of practical calibration of a large number of biological processes and set physiology in the way of becoming an exact science. The water-relations of the organism have always stood out as a subject of great importance, and as the main aspects are presented with less complication in plants, where the essential features are not complicated by a circulatory system, it has naturally followed that the principal contributions have been made by workers who attacked the problems involved from a botanical point of view.

Osmotic action, being earliest and best known, has had thrown upon it the entire burden of the explanation of the water-relations, and all of the mechanical action of the organism which might in any manner be attributed to pressures originating by the action of electrolytes. One contemplates departures from it, as set out in text-books, with regret; but some very substantial modifications of our conceptions with regard to these matters are long overdue.

The simpler phenomena of swelling and of changes of form due to the imbibition action of wood, starch and other material in a colloidal condition found place even in my preliminary directions for work: it was well recognized, however, that secretion, excretion and the accumulation of water anywhere in an organism were not fully comprehensible on the theory of osmotic action, and I can still recall that while trying out the simple tests in plant physiology which had been outlined for me, and which were calculated to give an encouraging sense of sufficiency to the student, the professor of biology was leading us into a consideration of the action of the epithelial cells and of other tissues which presented many features not explainable by osmosis. However much this inadequacy may have impressed my teacher, candor compels me to say that it did not bear too poignantly upon me, and I was willing to leave these as well as many other troublesome things to such all-embracing causes as "special physiological action" or any other convenient bogie, as being entirely too mysterious for a beginner.

Osmosis has indeed brought us far, and the briefest review will demonstrate the tremendous strides that have been made by its application. Our conceptions of turgidity and of processes which depend directly upon cell-pressures are so well-established as to be subject to but slight possible modification. It is not so, however, with many other phases of the physiology of the cell. The greater mass of an organism is colloidal, complex as to constitution, diverse as to reaction to acids, alkalies and electrolytes in general, and lastly having highly specific inter-actions among its constituents. It is bodies or masses of this kind that are to be dealt with when considering the action and morphology of the chromosome, chlorophyll bodies and cell-organs in general, as well as the nature and action of the membranes of the living organism The opinion is hazarded that further advances in cell-mechanics will await some more definite physical knowledge of the colloidal bodies whose evolutions and involutions are the center of the morphological interest in cytology. A systematization of the water-relations of these bodies, and of the changed qualities resulting from contact and action of other cell-constituents is demanded: determination of chemical structure is of ultimate importance, but not so immediately necessary to the physiologist, who would now welcome a return from the chemist and physicist of the service rendered them earlier by botanists.

The water-relations, now as earlier, hold the center of the stage in physiology, especially in plants. In a final analysis it might be truly said that it is to the immanence of this subject that the establishment of the Desert Laboratory is due. It may be profitable to discuss some of the problems which present themselves to those of us whose activities center at that institution, and to take a glance at the living material which has developed under water-conditions quite unlike those of this and other regions with a moist climate. I am confident that I speak with the concurrence of my colleagues when I say that whatever results of importance we may have accomplished must be attributed largely to the living plants available for our work and the environmental conditions which furnish a background for our experimentation.

If organic response to environic factors is to be taken as a potent means to evolution some striking features might be expected in the southwestern deserts; and when one looks up and down the slopes of Tumamoc hill, or across the washes to the bajadas of the Tucson mountains, types of vegetation not seen in regions with more moisture are seen everywhere. Furthermore, it needs only a brief acquaintance with the desert to know that the animals which find food and shelter in this vegetation show structures and habits equally pronounced.

Two general types of plants may be seen away from the streamways: one comprises species of annuals and perennials with retarded stems, branches reduced to spines, small, narrow, hardened and waterproofed leaves, which send their roots to only a moderate depth in the soil occupying a kettle-shaped mass, being of the generalized type of Cannon. It may be explained at this point that the moisture of desert soils available to plants is in the more superficial layers which are wetted by the rains. The spinose plants now under discussion contain a very small proportion of water: their bodies are hard, with a minimum of development of cortex or pith, and they hold only a small amount of sap in the protoplasts or suspension colloids of the cells. This juice, however, is characterized by the fact that it generally contains a very large proportion of salts or compounds which exert osmotic pressure. The state of the cells may be determined by the use of plasmolytic methods in which the strength of a solution, such as cane sugar or potassium nitrate, which will balance the solution in the cell is measured, or by extracting a certain measured amount of living material which has been crushed with distilled water and after the freezing point of this extract has been found the original pressure may be calculated. The simpler process of squeezing out sap and testing its freezing point can not be used in a large number of instances since the highest pressures that can be applied fail to bring out the scanty sap from some species. The use of such methods at the Desert Laboratory demonstrates that the leaves of the creosote bush (*Covillea,* or *Larrea*) (Fig. 1) may have

FIG. 1. *Covillea* (*Larrea*), THE CREOSOTE BUSH, THE MOST WIDELY DISTRIBUTED SHRUB WITH RESTRICTED SURFACES IN AMERICAN DESERTS. The leaves show osmotic pressures equivalent to over 75 atmospheres.

osmotic pressures of 75 atmospheres, the upper parts of the stems 35 to 60 atmospheres, and the basal portions of the stems 35 to 50 atmospheres. Fitting, by the use of plasmolytic methods on plants in the Algerian deserts at Biskra, found pressures in leaves of plants of this type of over a hundred atmospheres. These pressures would support a column of water 250 to 300 feet high.

It is notable that plants of this type are constantly in absorbent contact with the soil, and apparently continue to derive some water from it even in the driest times, as evinced by the fact that they wilt quickly when taken up. Such forms are very difficult to transplant. A misapprehension as to the influence of concentration of sap upon transpiration has long been current, and I must plead guilty to some participation in statements tending to perpetuate the mistake. It may be easily found, however, that even the maximum pressures noted above would not retard transpiration as much as ten per cent. from that which would take place with a sap of distilled water. One of my reviewers has recently made a variation of this mistake in suggesting that acidity would have a retarding effect on water loss. No foundation exists for such a supposition.

Almost any ordinary branching plant with broad leaves will, if forced to carry out its development under arid conditions, show some of the features of the type of desert plants described, and it is customary to assume that the causal conditions responsible for such forms are the desert factors: that we have here a direct adaptation or environic response which has become heritable in the strictest and fullest sense. This is a matter that deserves the fullest consideration. Meanwhile it will be perfectly safe to assume that such spinose forms represent the simplest or most elementary specializations of desert plants, and species with the most diverse morphological constitution may show alterations of this character. The sclerophylls of the American desert include species of *Prosopis, Acacia, Calliandra, Parkinsonia, Cercidium, Olneya* of the leguminous plants, *Covillea* and *Zizyphus* of the Zygophyllaceæ, *Fouqueria, Lycium, Koehberlinia, Condalia, Manzanita, Franseria, Jatropha, Sapindus, Vauquelinia, Quercus, Aster* and others.

Southwestern America has been arid for an extremely long period, not uniformly so, however. The researches of Professor Ellsworth Huntington, in which evidence has been obtained from ruins of structures built by man, of geological terraces, lake beds, strands and drainage lines in Central Asia, Palestine, and America, and also by the examination of the structure of the big trees of California, seem to justify the conclusion that variations in climate with regard to temperature and moisture have taken place within the last two thousand years that would be of profound biological importance. It seems fair to assume that similar oscillations, each movement of which might extend over a few hundred years, have taken place previously.

It is under these conditions therefore that we are to think of the evolution of the desert vegetation of the southwest, and present knowledge compels us to believe that much of it originated somewhere within the limits of the region which is arid at the present time. Perhaps the most important constitutents of this indigenous specialized flora are the cacti, which must have originated somewhere in the Mexican highlands in the Tertiary or later. This group is known to contain over a thousand species, and now extends through South America, its distribution offering some most highly localized occurrences of species. So rapid has been its evolution, and so wide the amplitude of its departures from the prototypes, that the relationship of the group is very difficult to determine.

Chief interest in the present connection lies in the fact that in the evolutionary movement the members of the group have undergone all of the specializations of the spinose forms in addition to a number of others of even more sweeping morphological importance. Stems have been reduced and branching restricted: leaves are retained by some; in others, such as the prickly pears, they appear only as rudiments dropping off before maturity, while in others, such as the great melon cacti and the sahuaro, they are not visibly represented at all. So far does the general reduction go in the *Echinocacti* or melon cacti that the adult plant consists of a short stem, a few inches, or at most less than two yards high, unbranched, and bearing only two types of spines which may be taken to represent the rudiments of atrophied organs, or specialized organs, largely according to the morphological prejudices of the observer. These plants represent the climax of specialization to desert conditions and the end result of the influence of aridity on the development of land vegetation.

In these succulents which constitute the highest group of desert plants, the cortex and medulla of the stems are exaggerated to an enormous extent and the greater bulk of the plant consists of a parenchymatous tissue with mucilaginous cell-contents, which gives to the

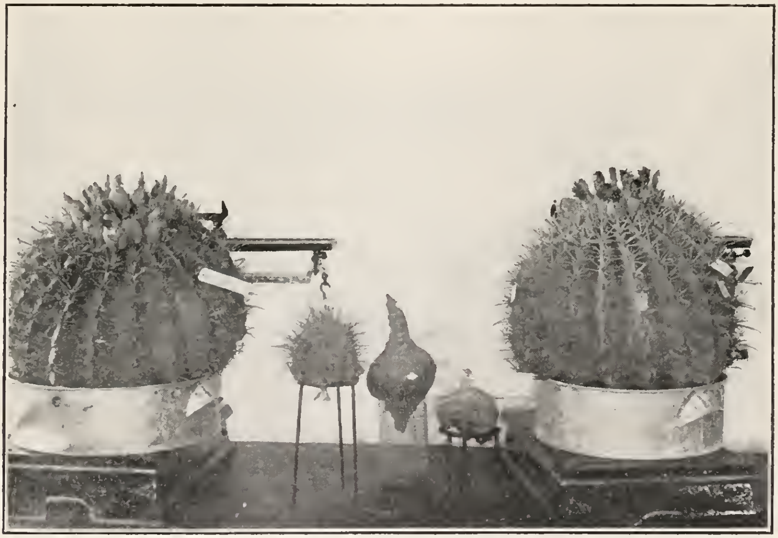

Fig. 2. A Group of *Echinocacti* and *Ibervillea*, isolated for Determination of the Rate of Water Loss. Succulents of this type have osmotic pressures of less than 12 atmospheres and absorb water only from soils containing large proportions of moisture. Some of these individuals have been without an external supply for thirty-eight months.

plant the physical qualities of a huge roll of jelly. The comparison may be made more inclusive, however. As the spinose plants have a sap high in electrolytes, mineral salts, or of substances showing osmotic activity, so these plants are rich in suspension colloids, and simulate a mass of gelatine capable of taking in and holding great quantities of water. The most sketchy knowledge of the colloids prepares one to learn that the sap of these plants shows a very low osmotic pressure under ordinary conditions of growth. The melon cacti of Arizona have a drinkable sap which shows but 3 to 5 atmospheres of pressure, the

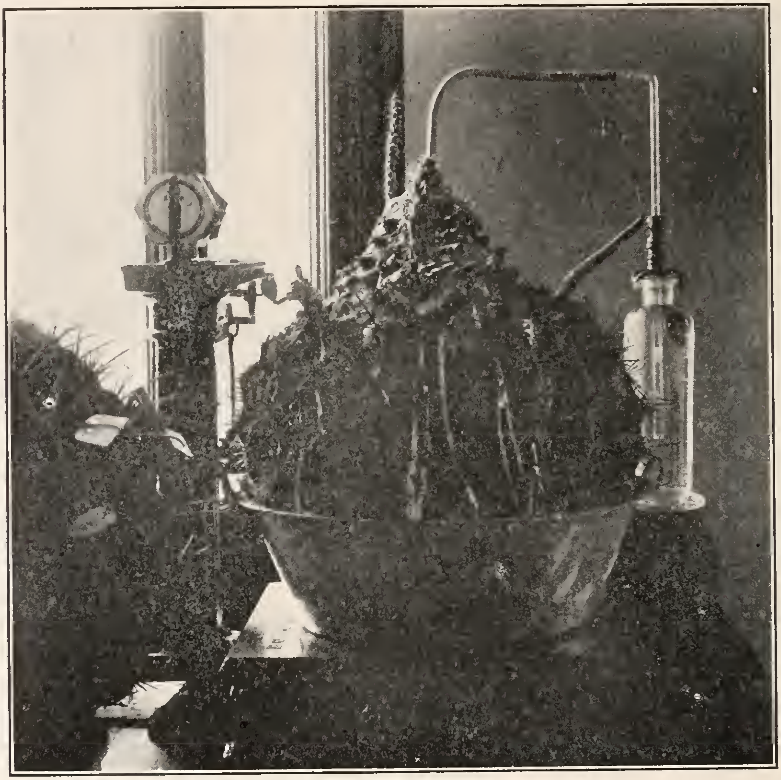

FIG. 3. AN INVERTED *Echinocactus* ABSORBING WATER THROUGH A CLAY CUP IMBEDDED IN THE BASAL PORTION.

great tree cactus with its mucilaginous juice varies from 7 to 10 atmospheres and the opuntias (cylindrical) as high as 10 to 12 atmospheres (Fig. 2.) These values are to be contrasted with those given above for the spinose forms, which are seven to thirty times as great and with such ordinary broad-leaved shrubs as the lilac, in which pressures from 20 to 30 atmospheres are the rule.

These purely physical features of the succulents are correlated with habits and modes of activity widely different from those of the spinose forms. The latter penetrate the soil more deeply and are in constant absorbent contact with the soil. The succulents of southwestern deserts, without exception, have a wide-spreading root-system horizontally disposed immediately under the surface of the soil in a layer which is wetted by even a slight precipitation. An increase in moisture is the stimulus which starts the development of myriads of small absorbent rootlets and these have an absorbent capacity which results in the passage of a very large amount of water into the body of the jelly-like plant within a very brief period. (Fig. 3.)

As the rains come to an end the soil moisture soon dries to a limit in which the absorbent elements of the cacti may not act, these die and the plant stands or sits inert, anchored by the heavier roots in a soil with which it bears almost no important physiological relations until the coming of the next rainy season. It was to determine some of the features of the behavior of these plants during periods of extended deprivation of water that my own observations on the water-balance were begun in 1908 and are still being continued.

It is pertinent to say at this point that the halophytes, fleshy plants of seashores and saline areas, are not succulents in the present meaning of the term. These forms contain a large proportion of water, but it is held at high pressures (*Cakile* as high as 50 atmospheres, according to Lloyd), their transpiration rate corresponds with the proportion of water which they contain and water loss is consequently rapid, and as a further consequence they wilt quickly. An interesting capacity to vary the pressure of the sap in the absorbing organs has been found by English botanists.

The transpiration or loss of water from leaves or green organs of a plant may be roughly compared to the drying out and shrinkage of drops of wet gelatine; but with the modification that comes from the enclosure of the gelatine in small capsules arranged inside a chamber whose bounding walls are fairly water-proof, but which have ventilating openings, hundreds of them to the square millimeter. It would be as if a room were piled full of parchment bags distended with thin mucilage; the walls of the bags would undoubtedly be wet and water vapor would be constantly given off into the air-spaces at a rate very little affected by the composition of the water with which the mucilage is moistened. Furthermore, if the windows were open, the water vapor would be carried out and the total amount remaining lessened constantly.

The accentuated conditions at the Desert Laboratory have been favorable for the observation of a phase of transpiration which has been noted there for the first time. The transpiration of a leaf increases with the rising sun in the morning and the rate is accelerated until sometime in the forenoon, when, with all of the atmospheric factors at an intensity that would facilitate water loss, the rate suddenly drops, with the stomata still open. The theoretical explanation offered for this break by Professor Livingston would assume that the outer walls of the jelly-like cells are coated with a film of water from which evaporation takes place and which is constantly supplied from the cell. When the evaporating power of the air causes a loss in excess of the rate at which the film may be renewed from the cell, the film breaks, and evaporation now may take place from the interstices of the walls only. If the wall of the cell were supposed to be of brick laid in mortar and coated with plaster, the plaster would correspond to the film and the mortar between the bricks to the water from which evaporation could take place after this "incipient drying," as it has been termed, has taken place.

Excessive water loss may proceed with or without the breaking of the film to a point where the turgidity or pressure of the cells is lessened, with the result that the leaf wilts. The wilting point is not a constant, but is mainly the product of the retentivity of the soil and of the evaporating power of the air, both of which may vary widely. The evaporating action of the air may be calibrated exactly at any time, and it is proposed by Professor Livingston that the standard of wilting point for a test species might be one of the most valuable expressions of the agricultural value of a soil.

The action of stomata inevitably comes up in any consideration of transpiration: the beautifully regular structure of these organs, and their delicate action, have led to some extremely fanciful interpretations of their self-regulatory mechanism. Time suffices only to say that the condition of the stomatal openings concerns not only transpiration but also photosynthesis and respiration, and any scheme of automatism for action in response to any one of these processes would at times be highly detrimental to the other functions. Of recent contributions to the physiology of these organs, Lloyd's consideration of the manner in which carbohydrates are drawn into the guard cells and are concerned in the making or loss of turgidity, and also his method of determination of the actual state of the stomata on a leaf at any moment by instantaneous fixation of a strip of detached epidermis must be reckoned to be of great importance. Frances Darwin has recently devised a porometer which measures the rate at which air may be pulled through a leaf from one surface to the other, thus obtaining a basis for the calculation of the average condition of the stomatal openings. Such refinement of methods and perfection of apparatus will permit a much more accurate calibration of leaf action than has been possible hitherto.

The enormous accumulations of water in the bodies of cacti and other succulents raise questions as to the part such liquid may play in the life of the plant and some observations to test the matter were begun in 1908. An afternoon in October, 1909, was spent in felling and cutting up a tree cactus (*Carnegiea* or *Cerus giganteus*), near the Desert Laboratory, which consisted of a single cylindrical trunk 18 feet in height. The total weight was nearly a ton, and a section was found to contain over 91 per cent. of water, showing that the entire plant held over seventeen hundred pounds of water, or about five barrels.

It has previously been pointed out that during the dry season these plants sustain only an anchorage relation with the soil, and that absorption ceases wholly. The experiments were therefore planned to detach a number of individuals of the sahuaro (*Carnegiea*), the melon cactus (*Echinocactus*), and various opuntias from the soil, place them on suitable supports in the accustomed upright position and thus simply lengthen the dry seasons to which they had been subject. Accidents in nature tear many individuals loose from the soil and they may not be able to perfect a new root-system for many months, so that the observations closely simulated happenings in the history of the species involved. Some of the test plants were placed in the open air, some in the more equable conditions of a well lighted laboratory room, a few were kept for periods of a few months in constant temperature dark room, and others were exposed to the full blaze of the Arizona sunlight, standing on a base of black volcanic rock, thereby avoiding none of the desiccating effects of the climate.

The formidable armature of the bulky bodies of these plants made their manipulation a matter of some difficulty and discomfort even with the best supports and harness that could be devised. The larger ones were placed on platform scales, where they were allowed to remain undisturbed. The majority, however, were mounted and two or three men were necessary to handle them in the weighings which were made at intervals correlated with the season and the rate of loss.

All individuals showed a high rate of loss when first taken from the soil, the excess being attributed to the evaporation from abraded surfaces of the roots and stems. Next it was found, of course, that the rate of loss was least during the cooler season, at which time an *Echinocactus* might lose as little as one forty-thousandth of its weight in a day, and on the other hand during many days in the hot dry season the daily loss was one three-hundredth of its total weight. The minimum of the tree cactus was one nine-thousandth of its total and the maximum was about that of the *Echinocactus*, although not measured under equivalent conditions.

Chief interest in the rate of loss, however, centers about the behavior of these plants from season to season, especially when the amount of water on hand was taken into account. In work of this kind it is found convenient to use a standard of succulency which calculates the number of c.c. of water to 100 sq. cm. of surface. Thus a great melon cactus weighing nearly a hundred pounds had a succulence of 3 on the scale noted, in which condition it transpired water at the rate of 10 g. daily. A year later the succulence had fallen but slightly, being 2.8; the rate of transpiration, however, had decreased to one half, being now but 5 g. daily.

The theoretical explanation of the sudden drop in daily transpiration given above will not suffice for this case which is a comparison of successive seasons. The slowness of the rate of loss would allow ample time for the diffusion from the great water-balance of the plant to take up a deficiency at any given surface. Morphological alterations are not found, and the theoretical explanation that presents itself would be that the colloidal condition of the walls, or inner membranes had been altered. The altered concentration of the cell-sap with its included acids and other substances might well be responsible for a change similar to that which takes place on the surface of a plate of jelly when acted upon by various reagents. A second phase of interest in the acids of the sap was found in their daily variations. Earlier the determinations of the acidity of the sap were made rather at random, with the general result that it was seen to be not affected by progressive desiccation. Within the last few months, however, Professor H. M. Richards has gone into this matter more exactly, with the astonishing discovery that the acidity of these plants is very great in the morning and decreases steadily throughout the day until evening, when it begins to rise and continues to increase until morning. So great is the amplitude of this change that a cactus may contain four times as much acid in the morning as at sunset. It is needless to say that the problem as to the making and fate of this acid is a matter that excites the keenest interest in connection with the respiration and food-construction processes in the plant. At present the change seems to be directly dependent on the course of the temperature. It is to be recalled that the water-holding power of the cell colloids must be notably affected by this variation in the acids of the cell.

The probability of the absorption of water vapor from the air by plants of the desert is one of perennial interest, especially to those who take a sentimental view of desert life. The spines of cacti, especially the large curved and hooked ones of the *Echinocacti,* will take up water vapor, as has been demonstrated more than once in my work, but the very small amount of moisture thus acquired is not available to the living cells and is quickly lost when the plants are exposed to direct sunlight. The bark of the ocotillo (*Fouquiera*) will absorb liquid water and yield it to growing tissues, as has been found by Lloyd, the hairs of some south African succulents have been found to absorb moisture, and the fleshy beach plants will absorb either water vapor or liquid water through the leaves, especially when in a desiccated condition. Doubtless the heavy fogs of the California coast are in this way a source of supply for *Cakile* and other halophytes. In none of these cases, however, is the existence of the plants concerned so dependent upon atmospheric absorp-

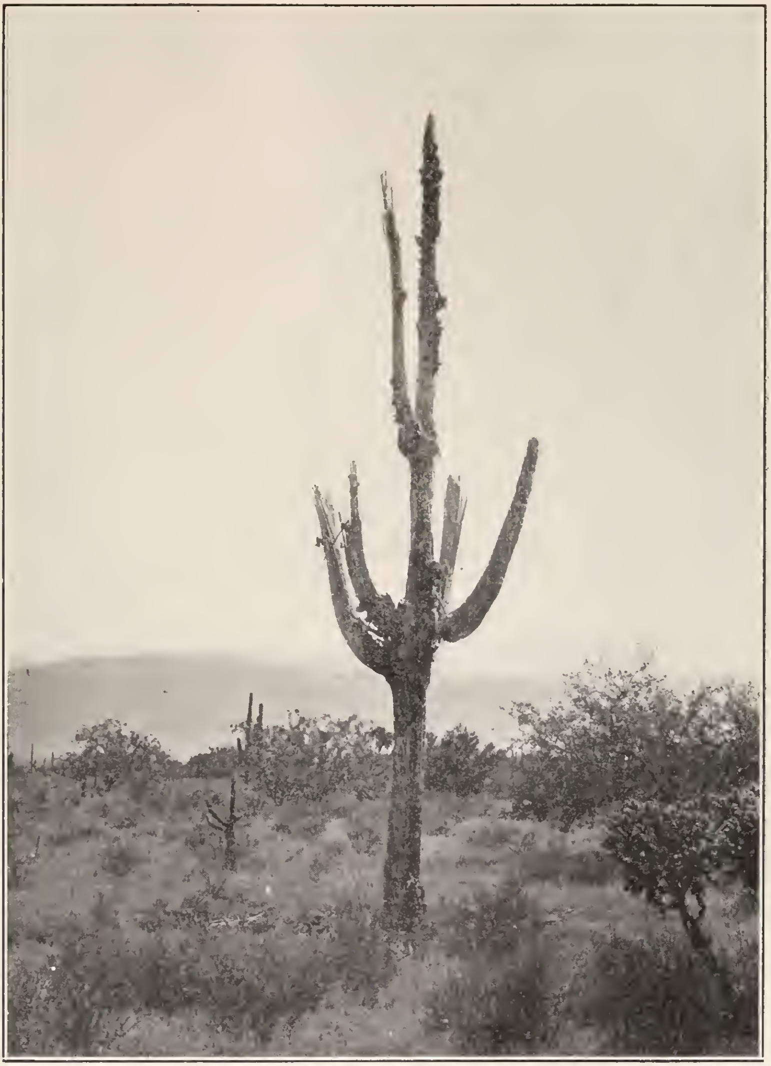

FIG. 4. A SAHUARO (*Carnegiea gigantea*) OF WHICH THE MAIN STEM HAS BEEN DEAD FOR OVER A YEAR, with three living branches, one of which bore flowers.

tion as has been found by Professor Peirce for the lichens which thrive in the fog channels leading up the valleys and over the passes along the Pacific shore.

Any study of this subject leads in the end to a consideration of the value of the great water-balances described in the life of the plant, and one naturally asks the question as to how long an individual might survive at the expense of its great accumulated supply, and what activity it may carry on while cut off from the customary supply of soil moisture. The replies to these queries vary widely with the species considered. The tree cactus may live a year or as long as two years in the open in Arizona upon its balance. Growth and reproduction are in the main inhibited, however, by any notable depletion. Sometimes, however, the death of the main trunk of a plant leaves a living branch held high in the air, and this may bloom, but this action must be due to the special stimulation of approaching death. (Fig. 4.) The melon cactus may survive one or two seasons in the open, although when given some shade individuals have been seen to live three years, carrying on some apical growth and flower formation with the usual rhythm. The prickly pears survive, grow and carry on reproduction for even longer periods.

FIG. 5. AN INDIVIDUAL OF *Ibervillea sonoræ* WHICH HAS PRODUCED VINES AND FLOWERS WHILE ISOLATED. This may be repeated many seasons.

So far as physiological usefulness is concerned, stores of water accumulated in tubers, bulbs or thickened underground organs are far more effective than thickened aerial stems or leaves in holding a water-balance available to the plant for extended periods. *Ibervillea*, the "guarequi" of Sonora, has a thickened stem homologous with the "Big Root" of California, which is a relative, and it has been cited many times to illustrate observations of an individual which is still alive although detached from a supply since 1902, and has not received any notable addition since 1901. (Fig. 5.) The corms of *Brodiæa* form new small corms during desiccation, which are plump with the diminished supply on hand, and this process continues until the balance reaches the vanishing point in three or four years. The observations of Professor Campbell show that plants with so little external appearance of water-storage as the liverworts may hold a balance in mucilage cells, a capacity shared by an extremely large number of species.

A review of the extensive data accumulated establishes the fact that *Echinocactus* may live for nearly three years at the expense of its water-balance, which may be depleted as much as 50 per cent. before death results. *Carnegiea* loses nearly 30 per cent. before serious results follow, although the extremely succulent seedlings of this plant may shrink to one third the original weight and still live.

Plants with a large water-balance are especially characteristic of the arid regions of southwestern United States, Mexico, some parts of South America and South Africa. It is notable that the great deserts of central Asia and Asia Minor, as well as the whole of north Africa, have but few native species of this habit. Some succulent *Euphorbias* are reported from India, but information concerning the occurrence of plants with a large accumulation of water in Australia is very meager. The physical causes which might be operative in inducing this habit in representatives of widely separated families are not known.

BUFFON AND THE PROBLEM OF SPECIES

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II

WE have thus far noted three generally disregarded but fundamental facts concerning Buffon's opinions about the nature of species. The first fact is that in his preliminary discourse in the first volume of the "Histoire Naturelle," in which he sought to apply the Leibnitian principle of continuity to natural history, Buffon's emphasis upon the continuity of the gradations between species probably had no evolutionary implications. The second fact is that the principal doctrine of this discourse is to the effect that only individuals exist in nature, while species exist only by grace of the human imagination, which, aided by human ignorance, sees sharp lines of cleavage among organisms where no such lines are. The third fact is that this doctrine was already tacitly but decisively abandoned in Buffon's second volume, where he represents species as real and well-marked natural entities, their limits being determined by the test of the sterility of the products of cross-breeding. There are, indeed, many later passages where the old phraseology incongruously recurs; but it recurs in contexts in which the reality of species is expressly insisted upon.

2. When the fourth volume of the "Histoire Naturelle"—the first dealing specifically with the lower animals—appeared in 1753, four years after the first three, Buffon's departure from the notions set forth in the preliminary discourse became still more evident. He had by this time, in the first place, been greatly impressed by the homologies in the structure of the vertebrates; he had come to see some significance in those facts of comparative anatomy which his own treatise—though more through the contributions of Daubenton than through his own—was for the first time setting in a clear light. The existence throughout at least all the immensely diverse vertebrate forms of an underlying unity of type, Buffon was, I suppose, the first to bring forcibly to the attention of naturalists and philosophers, as a fact calling for serious consideration and explanation.

> If we choose the body of some animal or even that of man himself to serve as a model with which to compare the bodies of other organized beings, we shall find that . . . there exists a certain primitive and general design, which we can trace for a long way. . . . Even in the parts which contribute most to give variety to the external form of animals, there is a prodigious degree of resemblance, which irresistibly brings to our mind the idea of an original pattern after which all animals seem to have been conceived. What, for example, can at first seem more unlike man than the horse? Yet when we compare man and horse point by

point and detail by detail, is not our wonder aroused rather by the resemblances than by the differences to be found between them? . . . It is but in the number of those bones which may be regarded as accessory, and in the lengthening or shortening or mode of attachment of the others, that the skeleton of the horse differs from that of the human body. . . . The foot of the horse (as M. Daubenton has shown), in appearance so different from the hand of man, is nevertheless composed of the same bones, and we have at the extremities of our fingers the same small hoof-shaped bone which terminates the foot of that animal. Judge, then, whether this hidden resemblance is not more marvelous than any outward differences, whether this constancy to a single plan of structure—which we can follow from man to the quadrupeds, from the quadrupeds to the cetacea, from the cetacea to birds, from birds to fishes, from fishes to reptiles—whether this does not seem to show that the Creator in making all these used but a single main idea, though varying it in every conceivable manner—so that man might admire equally the magnificence of the execution and the simplicity of the design.

But consideration of the anatomical homologies did not lead Buffon merely to pious reflections. He saw clearly and unequivocally declared that this unity of type forcibly suggests the hypothesis of community of descent. To one who considers only this class of facts, he wrote:

Not only the ass and the horse, but also man, the apes, the quadrupeds, and all the animals, might be regarded as constituting but a single family. . . . If it were admitted that the ass is of the family of the horse, and differs from the horse only because it has varied from the original form, one could equally well say that the ape is of the family of man, that he is a degenerate (*dégénéré*) man, that man and ape have a common origin; that, in fact, all the families, among plants as well as animals, have come from a single stock; and that all animals are descended from a single animal, from which have sprung in the course of time, as a result of progress or of degeneration, all the other races of animals. For if it were once shown that we are justified in establishing these families; if it were granted that among animals and plants there has been (I do not say several species) but even a single one, which has been produced in the course of direct descent from another species; if, for example, it were true that the ass is but a degeneration from the horse—then there would no longer be any limit to the power of nature, and we should not be wrong in supposing that, with sufficient time, she has been able from a single being to derive all the other organized beings.

Buffon thus presented the hypothesis of evolution with entire definiteness, and indicated the homological evidence in its favor. But did he himself regard that evidence as conclusive, and therefore accept the hypothesis? The passage cited is immediately followed by a repudiation, ostensibly on theological grounds, of the ideas which he has been so temptingly presenting.

But no! It is certain from revelation that all animals have participated equally in the grace of direct creation, and that the first pair of every species issued full formed from the hands of the Creator.[20]

This repudiation has been regarded as ironical, or as inserted merely *pro forma,* by those interpreters of Buffon who have made him out a thorough-going evolutionist. Unfortunately, nearly all these

[20] "Hist. Nat.," IV., 1753, p. 383.

writers—dealing somewhat less than fairly with their readers—have failed to mention that his rejection of the evolutionary hypothesis was not put forth by him as resting *exclusively* upon these religious considerations. If the words just quoted stood alone, it would, indeed, be scarcely possible to take them seriously. But they do not stand alone; they are directly followed by arguments of quite another order against the possibility of the descent of one *real* species from another; and the essence of the most emphasized of these arguments lies in the Buffonian conception of the nature of species, already expounded in the second volume. In other words, the fact of the sterility of hybrids, and certain other purely factual considerations, were urged by Buffon as conclusive objections against the theory of descent.

Specifically, his arguments against evolution are three: (1) Within recorded history no new true species (in his own sense of the term) have been known to appear. (2) There is one entirely definite and constant line of demarcation between species: it is that indicated by the infertility of hybrids.

> This is the most fixed point that we possess in natural history. No other resemblances or differences among living beings are so constant or so real or so certain. These, therefore, will constitute the only lines of division to be found in this work.

But why, it may be asked, should the sterility of hybrids be a proof of the wholly separate descent of the two species engendering such hybrids? This question Buffon does not neglect to answer. An "immense and perhaps an infinite number of combinations" would need to be assumed before one could conceive that "two animals, male and female, had not only so far departed from their original type as to belong no longer to the same species—that is to say, to be no longer able to reproduce by mating with those animals which they formerly resembled—but had also both diverged to exactly the same degree, and to just that degree necessary to make it possible for them to produce only by mating with one another." The logic of this is to me, I confess, a trifle obscure; but it is evident that Buffon conceived that the evolution from a given species of a new species infertile with the first could come about only through a highly improbable conjunction of circumstances. (3) Buffon's third reason for maintaining the fixity of species is the argument from the "missing links."

> If one species had been produced by another, if, for example, the ass species came from the horse, the result could have been brought about only slowly and by gradations. There would therefore be between the horse and the ass a large number of intermediate animals. Why, then, do we not to-day see the representatives, the descendants, of these intermediate species? Why is it that only the two extremes remain?

Taking these three arguments into account, then, Buffon arrives at this conclusion:

> Though it can not be demonstrated that the production of a species by

degeneration from another species is an impossibility for nature, the number of probabilities against it is so enormous that even on philosophical grounds one can scarcely have any doubt upon the point.[21]

However plausibly Buffon's incidental expressions of deference to the testimony of revelation may be regarded as perfunctory and insincere, it would be absurd to suppose that he was also ironical in these legitimate and ostensibly scientific (however poor) arguments for the fixity of species—arguments which are closely connected with that conception of the nature of species which was perhaps his most influential personal contribution to the biological ideas of his time. We must conclude, then, that, while he clearly envisaged the hypothesis of evolution as early as 1753, and recognized that there was some probable evidence in its favor, he then seriously believed that the preponderance of probability was enormously against it. It is certain that contemporary readers must have understood this to be his position.

The same doctrine—that true species, as determined by the sterility of hybrids, are real natural entities and constant units amid the otherwise infinitely variable phenomena of organic nature—is repeated and emphasized many times in subsequent volumes of the "Histoire Naturelle." Thus in volume five (1755) Buffon—trying to retain as much of the principle of continuity as could be made consistent with his present view—writes as follows:

Although *animal species are all separated from one another by an interval which nature can not overstep,* some of them seem to approximate one another by so great a number of relations, that there remains between them only so much of a gap as is necessary to establish the line of separation.[22]

In the same volume he insists upon the equal antiquity of all real species, in the very passage in which he emphasizes the possibility of a wide range of variation within the species:

Though species were formed at the same time, yet the number of generations since the creation has been much greater in the short-lived than in the long-lived species; hence variations, alterations, and departures from the original type, may be expected to have become far more perceptible in the case of animals which are so much farther removed from their original stock.[23]

This is advanced as a partial explanation of the extreme diversity of breeds in the canine species: the dog is a short-lived animal and has therefore been capable of a relatively great degree of diversification.

A little later (in Vol. VI.,[24] 1756) Buffon declares that "nature

[21] These, the most definite and decisive words on the subject to be found anywhere in Buffon's writings, have been strangely disregarded by most of those who have discussed his attitude towards evolutionism. Samuel Butler can scarcely be acquitted of suppressing the passage, fatal to his theory. For he quotes in full the opening part of the passage, leaving off abruptly at the point where Buffon begins to introduce his serious objections to the theory of descent. Cf. ''Evolution Old and New,'' p. 91.

[22] P. 59 (italics mine).

[23] P. 194.

[24] P. 55.

imprints upon every species its inalterable characters." In 1765—that is, at precisely the period during which we are told that Buffon "was expressing very radical views on the mutability of species"—we find him (in his "Second View of Nature," Vol. XIII.) giving his most extreme expression to the doctrine of the reality and constancy of genuine species. Here the language of the preliminary discourse concerning the relative significance in nature of the species and the individual has come to be completely reversed.

> An individual, of whatever species it be, is nothing in the universe; a hundred, a thousand individuals are nothing. Species are the only entities of nature (*les seuls êtres de la nature*)—perduring entities, as ancient, as permanent, as nature herself. In order to understand them better, we shall no longer consider species as merely collections or series of similar individuals, but as a whole independent of number, independent of time; a whole always living, always the same; a whole which was counted as a single unit among the works of the creation, and which consequently makes only a single unit in nature. . . . Time itself relates only to individuals, to beings whose existence is fugitive; but since the existence of species is constant, it is their permanence that constitutes duration, the differences between them that constitute number. . . . Let us then give to each species an equal right at nature's table; they are all equally dear to her, since she has given to each the means of existing, and of enduring as long as she herself endures.[25]

This sort of rhetoric is not the dialect of an evolutionist; it is almost that of a Platonist. And there is more in plainer language to the same effect:

> Each species of both animals and plants having been created, the first individuals of each served as models for all of their descendants. . . . The type of each species is cast in a mold of which the principal features are ineffaceable and forever permanent, while all the accessory touches vary.[26]

Many years later still, in 1778, there appeared the sub-division of the "Histoire Naturelle" which Buffon's contemporaries regarded as his most brilliant and most significant work—the "Époques de la Nature." This was a resumption on a grander scale, and upon new principles, of the task attempted in the "Theory of the Earth" in the first volume, thirty years before—an outline of planetary evolution. To the diffusion of evolutionary ways of thinking in the larger and vaguer sense, this treatise was a contribution of capital importance. Into the details of Buffon's geology I do not wish to enter in this paper. But it is worth while for our purpose to recall one or two striking facts about the "Époques." In it the writer, whom a recent German historian of biology has declared to have had a too little developed sense for the historical or genetic aspect of nature, attempted, in a far more comprehensive, more definite and more impressive way than any of his predecessors, to write the history of the gradual development of our planet from the time when, an incandescent ball, it was separated from the

[25] Vol. XIII., p. i.

[26] Vol. XIII., pp. vii, ix.

sun. The task was, of course, undertaken prematurely; but Buffon not only made the need of its eventual achievement evident, but also indicated two of the essential means by which it was to be accomplished: the study of present phenomena which can throw light upon the past processes through which existing conditions have been brought about; and the study of those natural "monuments which we ought to regard as witnesses testifying to us concerning the earlier ages." He insisted, moreover, with the utmost plainness upon (as it was then regarded) the extreme antiquity not only of the earth, but also of organic life. And in doing so he showed himself not at all disposed any longer to permit "revelation" to settle scientific questions. "How," he writes, "some one will ask me, do you reconcile this vast antiquity which you ascribe to matter with the sacred traditions, which give to the world only some six to eight thousand years? However strong be your proofs, however evident your facts, are not those reported in the holy book more certain still?" Buffon replies that he has all possible respect for scripture, but that it always pains him to see it used in this way. Doubtless there is no real conflict between its testimony and that of science; and he thereupon introduces what I suppose is the first of the long series of reconciliations of Genesis and geology. The six days were not really days, but long periods of time, and so forth. But in any case, he concludes, the Bible was originally addressed to ignorant men at an early stage of civilization, and was adapted to their needs and their intelligence. Its science was the science of the time, and ought not to be taken too literally. Finally, it is to be noted that in the "Époques" Buffon ceased to talk of the simultaneous creation of all species, and advanced the doctrine of the gradual appearance of different sorts of animals in conformity with geological conditions.

If, then, Buffon was desirous of inculcating the theory of the mutability of species, here was the place in which, above all others, he might be expected to do so fully and unequivocally. But here once more we find him reiterating the substance of his old doctrine:

> A comparison of these ancient monuments of the earliest age of living nature with her present products shows clearly that the constitutive form of each animal has remained the same and has undergone no alteration of its principal parts. The type of each species has not changed; the internal mold has kept its shape without variation. However long the succession of time may be conceived to have been, however numerous the generations that have come and gone, the individuals of each kind (*genre*) represent to-day the forms of those of the earliest ages—especially in the case of the larger species, whose characters are more invariable and whose nature is more fixed.[27]

By the "larger species" here, Buffon means those of greater size, such as the elephant and hippopotamus; and when he says that these are "especially" invariable, he means, as the whole context shows, not

[27] "Hist. Nat.," Supp., V., p. 27.

that any other species ever departs from its specific type, but that in these larger creatures even the "accessory touches" have been comparatively little altered.

Thus, in a long series of passages, from 1753 on, we find Buffon reiterating with explicitness and emphasis the same teaching, which has, for him, its principal bases in two of his most cherished conceptions: namely, in his conviction that the sterility of hybrids shows that species are real "entities of nature"; and in his embryological theory of "organic molecules" and of the "internal mold" which "casts into its own shape those substances upon which it feeds" and "can operate in the individual only in accordance with the form of each species." One of the first of modern naturalists to make the idea of organic evolution familiar to his contemporaries and to discuss it seriously, Buffon repeatedly rejected that theory, at all periods of his career; and he did so, not from timidity merely nor from an affectation of deference to scriptural authority, but upon reasoned grounds which he plainly stated and had every appearance of presenting as conclusive. Yet it is also undeniable, as will presently be seen, that he did not maintain this negative position without occasional waverings and doubts and at least one clear, though possibly inadvertent, self-contradiction.

3. In spite of his habitual emphasis upon the constancy of true species, Buffon insisted more than any of his predecessors, and more, perhaps, than any of his contemporaries, except Maupertuis and Diderot, upon the variability of organisms and the potency of the forces making for their modification.

> Though nature appears always the same, she passes nevertheless through a constant movement of successive variations, of sensible alterations; she lends herself to new combinations, to mutations of matter and form, so that to-day she is quite different from what she was at the beginning or even at later periods.[28]

The passage is from one of Buffon's later writings; but its close counterpart is to be found as early as 1756:

> If we consider each species in the different climates which it inhabits, we shall find perceptible varieties as regards size and form; they all derive an impress to a greater or less extent from the climate in which they live. These changes are made slowly and imperceptibly. Nature's great workman is Time. He marches ever with an even pace, and does nothing by leaps and bounds, but by degrees, gradations and successions he does all things; and the changes which he works—at first imperceptible—become little by little perceptible, and show themselves eventually in results about which there can be no mistake.[29]

For the most part these changes were clearly represented by Buffon as taking place only within the limits of species; they amounted merely to the formation of new "races" or varieties. Since his criterion of

[28] *Supp.*, V., 1778, p. 3.

[29] Vol. VI., pp. 59–60. I have borrowed Butler's excellent rendering of this passage.

identity of species (the possibility of interbreeding) did not essentially depend upon morphological similarity, he could with consistency suppose the descendants of a given pair to have departed to a very great (though not to an indefinite) degree, in the course of ages, from the form and external characters of their ancestors. It was, in other words, characteristic of his biological system that he set up an absolute distinction between species and varieties, gave an extreme extension to the notion of a variety, and sought to reduce the number of separate species as much as possible, by assuming—until the establishment of the sterility of the hybrids should prove the contrary—that most of the Linnæan species were merely varieties descended from a relatively small number of original specific types. Near the close of his essay "De la dégénération des animaux" (1766), Buffon writes:

> To account for the origin of these animals [certain of those found in America] we must go back to the time when the two continents were not yet separated and call to mind the earliest changes which took place in the surface of the globe; and we must think of the two hundred existing species of quadrupeds as reduced to thirty-eight families. And though this is not at all the state of nature as we now find it, but a state much more ancient, at which we can arrive only by induction and by analogies . . . difficult to lay hold of, we shall attempt nevertheless to ascend to these first ages of nature by the aid of the facts and monuments which yet remain to us.[30]

Here, clearly, is an evolutionary program, strictly limited by the assumption that there are irreducible ultimate species, yet tolerably ambitious: to regard all known kinds of quadrupeds as derived from thirty-eight original types, by modification in the course of natural descent; and to determine the general causes and conditions of the production of species in the ordinary sense, *i. e.*, of relatively stable varieties. These ideas occurred to Buffon too late to be made use of in his general plan for the classification of the quadrupeds; that plan, it will be remembered, was formed while he was unluckily under the influence of the principle of continuity. But in the volumes on birds, of which the first appeared in 1770, he had the opportunity for a fresh start; and he took advantage of it to introduce a method of distinguishing and classifying species which—within the limits already indicated—is expressly evolutionary in its principles.

> For the natural history of the birds I have thought that I ought to form a plan different from that which I followed in the case of the quadrupeds. Instead of treating of the birds . . . by distinct and separate species, I shall bring several of them together under a single *genus*. Except for the domesticated birds, all the others will be reunited with the species nearest to them and presented together as being approximately of the same nature and the same family. . . . When I speak of the number of lines of parentage, I mean the number of species so closely resembling one another that they may be regarded as collateral branches of a single stock, or of stocks so close to one another that they may be supposed to have a common ancestry and to have issued from that same original stock with which they are connected by so many points of resemblance

[30] Vol. XIV., 1766, p. 358.

common to them all. And these related species have probably been separated from one another only through the influences of climate and food, and by the lapse of time, which brings about all possible combinations and gives play to all the agencies that make for variation, for improvement, for alteration and for degeneration.[31]

Even the groupings which he gives, Buffon adds, can not be regarded, in the existing state of knowledge, as correctly and exclusively enumerating all the apparent species which are really akin to one another. The number of separate species which he lists, he intimates, is probably much too great. But at all events, he concludes with pride, his work is the first real attempt at an *ornithologie historique.*

The purpose of the present inquiry does not call for any extended exposition of Buffon's views about the causes of modification in animals and the ways in which quasi-species are formed. In the essay "De la dégénération des animaux" the subject is discussed at the length of over sixty quarto pages; the theories there advanced have been sufficiently accurately summarized by many previous writers. In brief, the factors in modification which he mentions as the most important are changes of climate (in which the most potent influence is temperature), changes of food, and the effects of domestication. But it is evident that he also believed in a general tendency to variation in the germ, and in the influence of acquired habits, of the use and disuse of parts, and of acquired lesions and mutilations. Thus he explains the humps, and the callosities on the knees and chest, of the camel and the llama as due to the habits of those animals under domestication. Similarly, the callosities on the haunches of the baboons arise from the fact that "the ordinary position of these animals is a sitting one—so that the hard skin under the haunches has even become inseparable from the bone against which it is continually pressed by the weight of the body." These theories, of course, take for granted the inheritance of acquired characters, which Buffon also (less cautious here than Maupertuis[32]) explicitly asserts. It is, I suppose, also well known that Buffon called attention (as Linnæus did independently) to the struggle for existence between species, due to the excessive multiplication of individuals, and pointed out how an equilibrium comes to be established (so long as external conditions remain constant) by means of this opposition.

It may be said that the movement of nature turns upon two immovable pivots—one, the boundless fecundity which she has given to all species; the other, the innumerable difficulties which reduce the results of that fecundity, and leave throughout time nearly the same number of individuals in every species.[33]

Buffon, in fact, rather over-worked this notion of a stable equilibrium, which rested upon the assumption of an approximate equality

[31] "Hist. des Oiseaux," I., 1770, preface.

[32] Cf. Lovejoy, "Some Eighteenth Century Evolutionists," Pop. Sci. Monthly, July, 1904, p. 248 n.

[33] "Hist. Nat.," V., 1755, p. 252.

among species in their endowment for the struggle for survival. This is perhaps one reason why it did not occur to him to think of that struggle as causing a process of natural selection, or to see in it a factor in the formation of so-called species.

4. It must be evident to the reader from all that precedes that Buffon's mind, throughout nearly the whole of his life, was played upon by two opposing forces. Quite apart from any illegitimate and external influences, such as fear of the ecclesiastics—of which too much has been made—his thought was affected by two conflicting sets of considerations of a factual and logical sort. He saw certain definite reasons for regarding species as the fundamental constants of organic nature; what those reasons were has been sufficiently indicated. But he also saw that there was some force in the argument from the homologies; and—what in his case was still more important—he was committed to the program of explaining the diversities of organisms, so far as might be, by the hypothesis of modification in the course of descent; he was deeply impressed by the fact of variability; and he held to a theory of heredity (namely, of the heritability of acquired characters) which acted as a sort of powerful undertow towards a generalized evolutionism. Add to this that he was little careful of consistency and extremely careful of rhetorical effect—and it is not surprising that he occasionally forgot one side of his doctrine in emphasizing the other. There is one and, so far as I can discover, only one passage in which he seems categorically to contradict his ordinary teaching of the impossibility of the descent of really distinct species, sterile *inter se,* from common ancestors. This occurs at the end of the chapter on "Animals Common to Both Continents" (Vol. IX., 1761).

> It is not impossible that, without any deviation from the ordinary course of nature, all the animals of the New World may be at bottom the same as those of the Old—having originated from the latter in some former age. One might say that, having subsequently become separated by vast oceans and impassable lands, they have gradually been affected by a climate which has itself been so modified as to become a new one through the operation of the same causes which dissociated the individuals of the two continents from one another. Thus in the course of time the animals of America have grown smaller and departed from their original characters. This, however, should not prevent our regarding them to-day as different species. Whether the difference be caused by time, climate and soil, or be as old as the creation, it is none the less real. Nature, I maintain, is in a state of continual flux and movement. It is enough for man if he can grasp her as she now is, and cast but a glance or two upon the past and future, to endeavor to perceive what she may once have been and what she may yet become.

Here Buffon seems either to have forgotten or to have deliberately discarded his own usual criterion of diversity of species. He does not propose to inquire whether the American species are capable of having fertile progeny when mated with their respective congeners in the old world, but predicates difference of species solely on the ground of dissimilarity of form; and to the distinct species so determined he attributes an identical origin. But it is possible that he has here merely lapsed (as he apparently does occasionally elsewhere) into the terminology in which he was brought up, and is using the word species in the Linnæan sense rather than in his own.

More significant, perhaps, than this possibly inadvertent inconsistency is the fact that, in his fourteenth volume[34] (1766), Buffon seems to raise explicitly the question—though only *as* a question—whether, after all, descent with modification may not extend to species as well as varieties.

> After surveying the varieties which indicate to us the alterations that each species has undergone, there arises a larger and more important question, namely, how far species themselves can change—how far there has been a more ancient modification, immemorial from all antiquity, which has taken place in every family, or, if the term be preferred, *in all the genera in which species that closely resemble one another are to be found.* There are only a few isolated species which are like man in forming at once a species and a whole genus. Such are the elephant, rhinoceros, hippopotamus and giraffe, which constitute genera, or simple species, and descend in a single line, with no collateral branches. But all other races have the appearance of forming families, in which we may perceive a common source or stock from which the different branches seem to have sprung.[35]

Even here one can not be wholly sure that Buffon is not referring to Linnæan species, and using the word genera to indicate what he usually means by species in the strict sense. Assuming, however, that he is speaking of "true" species, it must be observed that while he raises the question of their mutability, he does not answer it finally in the affirmative. For the passage is shortly followed by that cited earlier in this paper, in which Buffon, though he derives many species traditionally regarded as distinct from a common stock, yet finds even in "the first ages of nature" thirty-eight irreducible diversities of specific type among quadrupeds.

There is, however, one peculiarly interesting essay in which Buffon shows himself a little dubious even about that "most fixed point in nature" upon which his usual doctrine of the reality and constancy of species was based—namely, the fact of the sterility of hybrids. As I have already mentioned, this seemed to him so central a point in natural history that he for many years assiduously collected data concerning it, and caused experiments bearing thereon to be made and carefully recorded at his own estate at Montbard. The results of these inquiries, which he reports in the chapter "On Mules" (in the third supplementary volume, 1776), led him to the conclusion that hybrids are not necessarily without hope of posterity. On the testimony of an affidavit from a gentleman in San Domingo, Buffon declares that in hot climates mules have been known to beget offspring of mares, and females of their

[34] Just a year earlier we have found Buffon using the most exaggerated language possible about the changelessness of species.

[35] Vol. XIV., p. 335; italics mine.

kind to breed with horses. "One was therefore wrong formerly in maintaining that mules are absolutely infertile." Other experiments in the crossing of goats and sheep, dogs and wolves, canaries and goldfinches, are recited; they all go to show that sterility is merely a question of degree.

> All hybrids (*mulets*), *says prejudice,* are vitiated animals which can not produce offspring. No animal, *say reason and experience,* is absolutely infertile, even though its parents were of separate species. On the contrary, all are capable of reproduction, and the only difference is a difference of more or less.[36]

That hybrids are *relatively* infertile, and probably incapable of breeding with one another, Buffon still maintains; "their infecundity, without being absolute, may still be regarded as a positive fact." Something, therefore, is still left of his test of unity of species. But now that it seemed to be reduced to a mere difference in degree, it was no longer the sharp-cut, decisive, impressive thing that it had at first appeared. And, feeling that his criterion of species had a good deal weakened, Buffon was led—not, indeed, even now to an altogether unequivocal affirmation of the descent of real species from one another—but to a confused, half-agnostic utterance, in which he seems to take at least the possibility of such descent for granted:

> In general, the kinship of species is one of those profound mysteries of nature which man will be able to fathom only by means of long and repeated and difficult experiments. How, save by a thousand attempts at the cross-breeding of animals of different species, can we ever determine their degree of kinship? Is the ass nearer to the horse than to the zebra? Is the dog nearer to the wolf than to the fox or the jackal? At what distance from man shall we place the great apes, which resemble him so perfectly in bodily conformation? Were all the species of animals formerly what they are to-day? Has their number not increased, or rather, diminished (*sic*)? . . . What relations can we establish between this kinship of species and that better known kinship of races within the same species? Do not races in general arise, like mixed species, from an incapacity in the individuals from which the race originated for mating with the pure species? There is perhaps to be found in the dog species some race so rare that it is more difficult to breed than is the mixed species produced by the ass and the mare. How many other questions there are to ask upon this matter alone—and how few of them there are that we can answer! How many more facts we shall need to know before we can pronounce—or even conjecture—upon these points! How many experiments must be undertaken in order to discover these facts, to spy them out, or even to anticipate them by well-grounded conjectures![37]

This passage certainly indicates a strong inclination towards an acceptance of a thorough-going doctrine of descent; yet in Butler's lengthy compilation of the evidences of Buffon's evolutionism it is not cited at all! The volume containing it, says Butler, offers "little which throws additional light upon Buffon's opinion concerning the mutability of species"![38] In truth, it offers one of the best of the

[36] *Supp.*, III., p. 20; the italics are Buffon's.
[37] *Supp.*, III., 1776, pp. 32–33.
[38] "Evolution Old and New," p. 165.

extremely few passages which give some plausibility at least to the theory that Buffon was continuously working towards an unqualified transformism and actually arrived at that position in his later life. But if he reached it (which his language just quoted does not quite justify us in declaring) he did so only in a transient mood. For, as we have already seen, in 1779, in the "Epoques de la Nature," we once more find him asserting—though no longer upon the ground of the sterility of hybrids—that the "constitutive form" of each separate species is the same to-day as in "the earliest ages."

5. It is more important, and it is commonly easier, to determine what opinions a man's writings tended to encourage than to determine what opinions he actually held. Mind-reading is perhaps no essential part of the history of science. If, then, in conclusion, we raise the more important question with respect to Buffon, it is evident that his work both fostered and hindered the propagation of evolutionary ideas in biology. Earlier than any other except Maupertuis, he put the hypothesis of organic evolution before his contemporaries in a clear and definite form. He called to their attention, also, the facts of comparative anatomy which constitute one of the principal evidences for that hypothesis. Throughout the rest of the century we never cease to hear about the wonderful "unity of type" characteristic of the vertebrates and perhaps of all living things. It was this consideration which led Kant as near to evolutionism as he ever came; Herder and Goethe are full of it, though the former never admitted its full evolutionary consequences; and all, it is evident, learned it directly from Buffon. He, says Goethe, was the first to recognize *eine ursprüngliche und allgemeine Vorzeichnung der Tiere*. Buffon, moreover, once and for all inscribed upon the program of natural history, as its primary problems, the reduction of the number of separate species to a minimum, the derivation of highly divergent forms from a common origin through natural descent, and the discovery of the causes and methods of modification. He, finally, did more than any one else to habituate the mind of his time to a vastly (though not yet sufficiently) enlarged time-scale in connection with the history of organic nature, a necessary prerequisite to the establishment of transformism.

These were great steps in the progress of evolutionism. But it is equally true that Buffon probably did more than any other eighteenth century writer to check the progress of evolutionism. He did so partly by the authority which, for his contemporaries, attached to those personal utterances of his favorable to the doctrine of immutability. These utterances were far more numerous and more categorical than those which could be quoted on the other side; and they certainly were not taken as ironical by the average reader of the period. But, what is still more important, Buffon put into currency what passed for a scientific and serious argument against any wholesale theory of descent. In the eyes of many learned men of his own and later generations, perhaps his chief single contribution to science was his definition of species. This, as I have recently pointed out,[39] was regarded as of immense importance by Kant, and was, indeed, the starting point and the controlling principle of that philosopher's biological speculations. "It is Buffon," wrote Flourens as late as 1844, "who has given us the positive character of a species." Now before the Buffonian criterion of species was propounded, there already existed a tendency towards evolutionism, fostered by the principle of continuity and by such embryological conceptions as those of Maupertuis—a tendency to disregard species altogether and to infer from the variability of individuals to an unlimited and rather promiscuous mutability of the successive generations of living things. If it had not been for Buffon, transformism would probably have developed at first[40] through the increase and diffusion of this tendency; and its development might well, in that case, have been more rapid. But when species came to be regarded as real "entities of nature," determined by the objective criterion of the sterility of hybrids, this somewhat too facile evolutionism received a check, and a certain presumption of the constancy of true species seemed to be created. This presumption had all the more force because it left room for a large measure of mutability in the case of varieties, and thus gave a sort of appeasement to the strong impulse towards genetic modes of thought which was already active in the mid-eighteenth century. But more than all this, Buffon, as we have seen, from the first managed to associate with his definition of species the assumption that the sterility of one kind of animal when crossed with another was a character that (unlike almost all others) could not have been produced in the course of descent with modification. And this supposition that the sterility of hybrids was incapable of an evolutionary explanation long remained a serious obstacle to the acceptance of the theory of descent, even with those little influenced by theological prejudices against the theory. We find even Huxley in 1862 troubled over the difficulty. In his Edinburgh lectures of that year "he warned his hearers of the one missing link in the chain of evidence—the fact that selective breeding has not yet produced species sterile to one another." The doctrine of descent was merely to be "adopted as a working hypothesis, . . . subject to the production of proof that physiological species may be produced by selective breeding."[41] Since Buffon appears to have been the first to emphasize the notion of physiological species, and to give currency to the supposition that the sterility of hybrids affords a presumption against any thorough-going transformism, he must be regarded as having done more than almost any man of his time to counteract the tendency which he also, perhaps, did more than any other to promote.

[39] POPULAR SCIENCE MONTHLY, January, 1911, pp. 37–38.

[40] Cf. Lovejoy, POPULAR SCIENCE MONTHLY, July, 1904, p. 248.

[41] Huxley's "Life and Letters," I., 193.

PROTOZOAN GERM PLASM

By Professor GARY N. CALKINS

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IN his classical essays on the nature of the germ plasm, Weismann, more than twenty years ago, drew a distinction between that protoplasm destined for the perpetuation of the race and that needed by the organism for its ordinary functions of moving, eating, digesting, etc. The former, which he designated germ plasm, in Metazoa is early differentiated from the latter, and in some forms may be distinguished as the rudiments of a germinal epithelium even before the end of segmentation. The latter develops into the vegetative organs of the adult and serves to nourish and support the former. The distinction, therefore, especially in the higher Metazoa, indicates a real difference in potential, and the vegetative cells have no primary reproductive functions. In lower Metazoa the distinction is not so clear, many of the vegetative cells turning to germ cells either in groups or singly.

Protozoa, or animals consisting of one cell only, were set apart by Weismann as differing from Metazoa in not showing this somatic germinal differentiation, and he regarded them all as potential germ cells. Furthermore, since germ cells have the possibility, at least, of continued life, while somatic cells die, he assumed that Protozoa are potentially immortal, while natural death is the penalty Metazoa must pay for the privilege of differentiation.

Weismann's hypothesis is certainly seductive, and, viewed superficially, would seem to indicate a fundamental difference between the unicellular and the multicellular animals. Protozoa, however, are more than mere single cells, comparable with the isolated tissue cells of higher animals. They must be regarded as organisms, complete in themselves and comparable, therefore, with the whole animal of higher type and not with any one of its cells. Like the entire Metazoon, it excretes the products of destructive metabolism, it secretes many different types of by-products; it moves, obtains food, swallows, digests and assimilates it through the action of digestive fluids; in short, it performs all of the functions which distinguish animals from plants. Finally, like higher types again it reproduces its kind by processes relatively as simple as the functions of digestion or nervous response are simple when compared with these functions in Metazoa. In such complete organisms, therefore, it is a logical inference to consider the protoplasm of a protozoon as made up of widely different elements equivalent in function to the aggregate of cells making up the metazoon, and with some parts at least having the power to contract and move, some to digest food, some to secrete, others to excrete and still others, finally, to reproduce. Considered in this sense the cell theory as applied to the Protozoa is obviously inadequate.

The especial portions of the protoplasm that have to do with these several different functions of the protozoon can be identified in many cases as structurally different from the remainder, especially those parts which have to do with movement and with the perpetuation of the race, *i. e.*, the germ plasm. In the majority of Protozoa this portion of the protozoon is clearly differentiated, one time or another, from the remainder of the cell, and this justifies us in taking issue with Weismann, and with the majority of those who write casually about the Protozoa, as having no somatic cell elements and therefore no possibility of natural death. If it can be shown that there is a specific germ plasm in these unicellular animals, then the matter of immortality differs in no essential way from the same problem in Metazoa or Metaphyta where the germ cells have a possibility of endless existence. The evidence points to a common and universal law that continued life is an attribute of an especially endowed protoplasm, termed germ plasm, which forms the material basis of the reproductive cells.

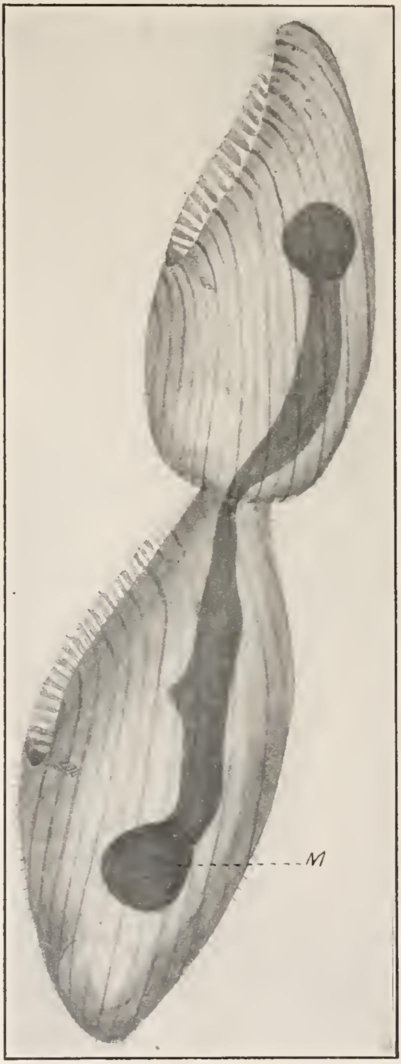


FIG. 1. *Original.*

The history of single Protozoa, if taken superficially, seems to point to the fact that the protoplasm of these cells does not die a natural death, but continues to live in successive generations of similar individuals. The individual cell appears to be entirely self-sufficient; it captures food, digests it, grows to maximum size and then divides (Fig. 1). The original individual cell no longer exists, although it has not died; its protoplasm is now distributed between two daughter cells. In the same way these cells grow old in turn, divide into two each, and so on apparently in endless succession of cell generations. Obviously if this could keep on indefinitely there would be a basis for the view that Protozoa are immortal. They do not keep this up, however, but there comes a time when the nature of the protoplasmic make-up changes, and processes similar to fertilization in Metazoa supervene.

Fig. 2. *Original.*

In the great majority of parasitic protozoa and in most free-living forms that have been studied in culture, there comes a period when certain cells of the race, or specialized parts of the protoplasm of all of the cells of the race, undergo marked changes, different from any vegetative phase, and reorganization of the old individual or formation of new ones is the outcome. This result is brought about by conjugation or the union of two cells in more or less complete coalescence, during which an interchange and mixture of germ plasms is accomplished (Fig. 2).

In some of the best-known forms of Protozoa, notably in *Paramecium caudatum,* the conditions are quite different from those of the majority of protozoa and too many generalizations have been made upon the comparatively rare phenomena which are manifested in this "slipper animal" and its immediate allies. In the conjugation of *Paramecium* two individual cells unite very much as do Blepharisma cells. In each individual there are two types of nuclei, one, a large macronucleus, plays no part in the fertilization process, but, sooner or later, disintegrates and dissolves in the cell. The other is a minute micronucleus, which divides three successive times, giving rise to a number of micronuclei, which, with the exception of two germ nuclei, also disintegrate and dissolve in the cell. These two germ nuclei are sexually differentiated, one is smaller than the other, and migrates into the other cell of the pair, there uniting with the stationary larger form of nucleus (Fig. 3). Thus there is a mutual fertilization of the two

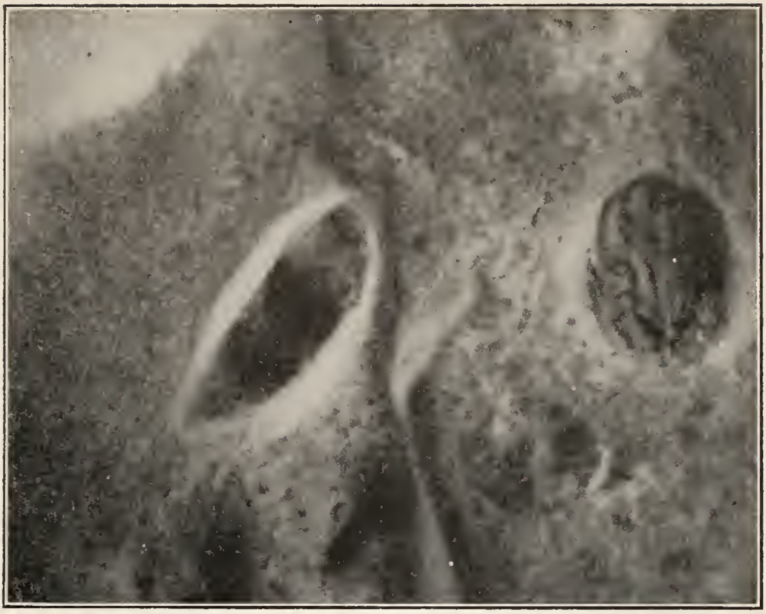


FIG. 3. *After Calkins.*

cells which now undergo, separately, the later stages of development. These stages consist in the division of the fertilization nucleus and new formation from the division products, of the new macronucleus and the new micronucleus (Fig. 4).

After such a process of fertilization it would seem that the individuals are pretty much as they were before except for the complete reorganization of the nuclear apparatus, and there is a certain justification for the Weismann conception. But the phenomena in *Paramecium* and allied forms, like their cell differentiations, are highly specialized and are unlike the fertilization processes in the majority of Protozoa.

The enormous group of Sarcodina, including more than four thousand species of Radiolaria and some thousand or more species of Foraminifera, Heliozoa and Rhizopods, presents a fairly uniform picture of the germ plasm and the processes of fertilization. For purposes of illustration and comparison I will describe two types selected from this great group of forms—one a marine foraminiferon, *Polystomella crispa,* the other a common fresh-water rhizopod *Arcella vulgaris.*

So far as known, each species of Foraminifera exists in two forms known as the microsphæric and the megalosphæric forms, so called because of the small and large size of the central or initial chamber of the shell (Figs. 5 and 6). These two forms correspond with the asexual and the sexual generations of metagenetic hydrozoa, the microsphæric type corresponding with the hydroid, the macrosphæric type with the medusa generation. Like these cœlenterates, the microsphæric type reproduces asexually while the macrosphæric type reproduces sexually. Like them also, the asexual generation gives rise to the sexual and the latter, again, to the asexual, hence there is a typical alternation of generations. Like the cœlenterates, again, the sexual generation acts as a nurse for the important germ plasm. Let us see how this works out in the case of *Polystomella crispa.*

FIG. 4. *After Calkins.*

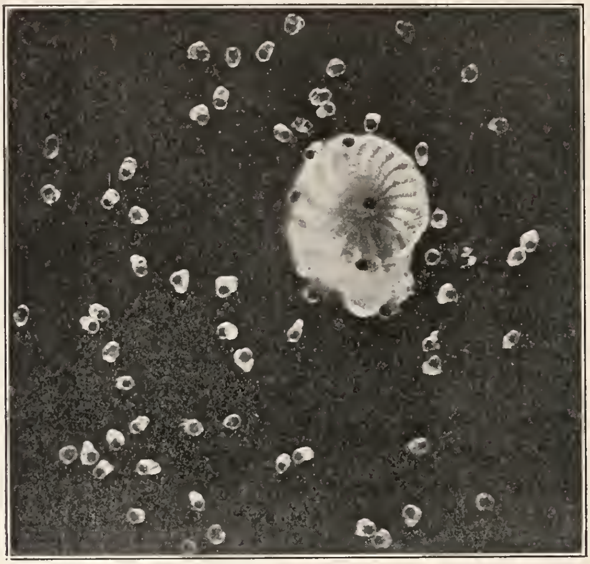
The young individual of *Polystomella* secretes a shell of calcium carbonate and grows by feeding on various minute animals and plants. Its nucleus divides by mitosis and the protoplasmic mass increases in size but does not divide with the nucleus. A new shell chamber is formed partly enclosing the first one. Further division of the nuclei, increase of the plasmic mass and new chamber formation continues with constant feeding until a typical *Polystomella* shell is formed, containing a relatively great protoplasmic mass and hundreds of nuclei. When mature, all of the nuclei save one or two break down into thousands of

FIG. 5. *After Lister.*

minute particles of chromatin which are distributed throughout the protoplasm in the form of fine granules. Authorities differ somewhat in regard to the next changes of the nuclei. If we accept Schaudinn's

FIG. 6. *After Lister.*

account, verified by Winter, the protoplasm of the microsphæric individual breaks down into small fragments, each fragment enclosing a number of these granules of chromatin, which coalesce later to form one single nucleus. If we accept Lister's account the coalescence occurs before the breaking down of the protoplasmic mass. All observers agree, however, that hundreds of minute nucleated "embryos" arise



Photograph by J. J. Lister.
FIG. 7. *Polystomella crispa.* Liberation of pseudo-podiospores from the megalosphæric individual.

by fragmentation of the parent protoplasm (Fig. 7). The breaking down of the original nuclei is an important step, for by this process the important germ plasm is formed, which in the finely granular state described was named by Hertwig the chromidia.

The small "embryos" leave the parent organism in swarms (Fig. 8), and the calcareous shell is finally deserted. Each "embryo" then grows into a megalosphæric or large-chambered individual in which the primary nucleus remains single for a considerable period. New chambers are formed about the primary central chamber and a new adult individual results from the continued growth. The history of the nucleus, however, is quite different from that of the microsphæric individual. The protoplasm contains a large primary nucleus which ultimately degenerates and disappears. During life of the individual, however, this nucleus gives rise by chromatin "secretion" or by fragmentation, to an immense number of minute nuclei which are distributed throughout the protoplasmic mass. Each nucleus becomes surrounded by a thickened zone of protoplasm and then each divides twice, thus increasing the number of the zones. All of the protoplasm is utilized in this zone formation, with the exception of a small portion surrounding the original "primary" nucleus, these parts degenerating and disappearing. Preparations of the decalcified individual at this period show hundreds of minute nucleated masses completely filling the shell space (Fig. 6). In life, these emerge in swarms, each in the form of a tiny bi-flagellated swarmer. The swarmers are gametes which

FIG. 8. *After Calkins.*

conjugate with similar gametes from another individual (Fig. 8, A). The flagella are thrown off after union, the nuclei unite, and each united pair, as a fertilized cell, or zygote, develops into a new microsphæric individual.

In *Polystomella,* therefore, fertilization is accomplished, not by union of the parent individuals as in *Paramecium,* but by coalescence and fusion of minute gametes which contain portions of the specific germ substance in the form of chromidia.

Arcella vulgaris, a common fresh-water shelled rhizopod, has a much more simple life-history. The nucleus of the young form soon divides, so that most *Arcella* specimens contain two primary nuclei (Fig. 9). From the very outset, furthermore, each nucleus secretes a chromatin substance which collects in a zone about the periphery of the cell. This substance is not granular like the chromidia, but has a similar origin from the nucleus, and has the same germ-plasmic fate as chromidia, so that Hertwig was justified in calling it a "chromidial net." When the organism is mature, minute nuclei condense out of the substance of this network, hundreds of them being formed (Fig. 10). As in *Polystomella,* each nucleus becomes surrounded by a zone of protoplasm, and, finally, a large number of small swarmers emerge from the shell mouth, leaving behind in the shell the two primary nuclei and a portion of the protoplasm as a degenerating residue. The swarmers are dimorphic,

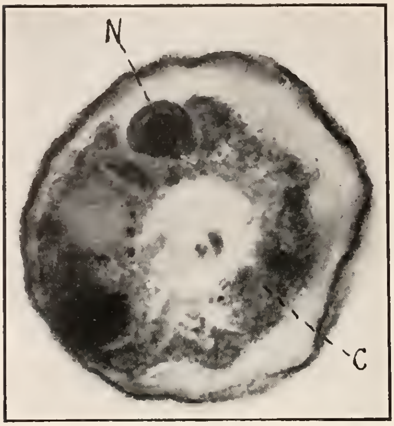


Fig. 9. *Original.*

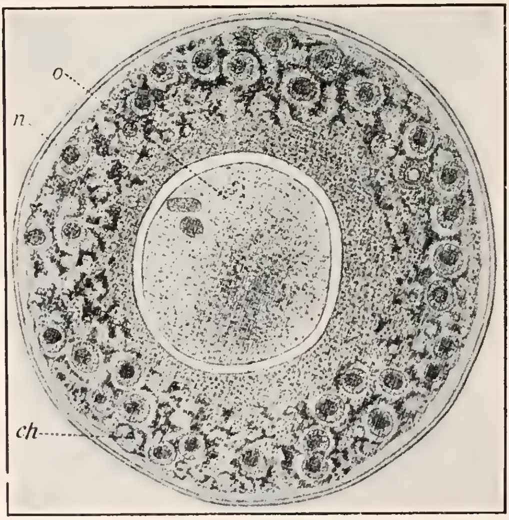


Fig. 10. *After Hertwig.*

some are macrogametes, some microgametes (Fig. 11). These fuse two by two, a macrogamete with a microgamete, and the resulting zygote develops into the normal form.

In *Arcella*, therefore, as in *Polystomella*, there is a definite germinal protoplasm composed essentially of chromatin which gives rise to new cycles of organisms, while a portion of the original organism, including the primary nucleus and a quantity of protoplasm, degenerates and dies. We can speak of germinal and somatic protoplasm in these cases, and with equal right in all of the thousands of allied species of protozoa, as well as in the case of any higher animal.

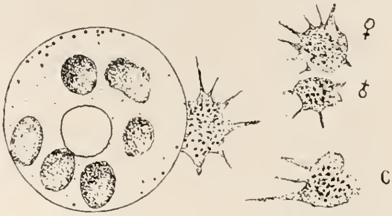


FIG. 11. *After Elpetiewsky.*

A still more interesting case of specific germ-plasm formation is given by a type of Gregarine belonging to a group of parasitic Sporozoa. In all of the Gregarines there is a segregation of the germ plasm and a residual somatic protoplasm which degenerates and dies a somatic death. One of the most striking illustrations of this type is the case of *Ophryocystis mesnili,* a parasite of beetles. Unlike the cases cited above, most of the gregarines do not reproduce asexually. *Ophryocystis,* however, is one of the exceptions to the rule, the individuals reproducing by simple division until the protoplasm becomes mature, when, as in *Paramecium,* two cells come together in conjugation. The single nucleus of each cell divides and one of the products becomes a "somatic" nucleus, to use Leger's term, while the other daughter nucleus in each cell divides again (Fig. 12, *A–G*). One of these corresponds to a polar body in the metazoon egg, the other is the gamete, or germ, nucleus. In each cell this nucleus collects about itself, possibly through the secretion of nuclear material which transforms the surrounding stuff, a denser zone of protoplasm, which, with the nucleus, forms a gamete within the body of the parent cell. The two gametes thus formed fuse while in the space which their formation has left in the parent somatic, or nurse cells. The latter ultimately wither up and die. After union of the two gametes, the sporoblast gives rise to eight germs or sporozoites, each capable of developing into an ordinary vegetative form when under the proper conditions of environment (Fig. 12, *H–N*).

Here in Gregarines, therefore, as in rhizopods, we see a clearly defined difference between germ plasm and somatic plasm, the latter dying, as in the Metazoa, the former capable of endless development. Unlike the rhizopods, however, the germinal chromatin is retained in the primary nucleus until full maturity of the cell and does not appear in the cytoplasm in the form of chromidia.

Turning after this excursion into other fields of Protozoa, to the case of *Paramecium*, it will be seen that the conditions are entirely different from those which accompany conjugation in the majority of

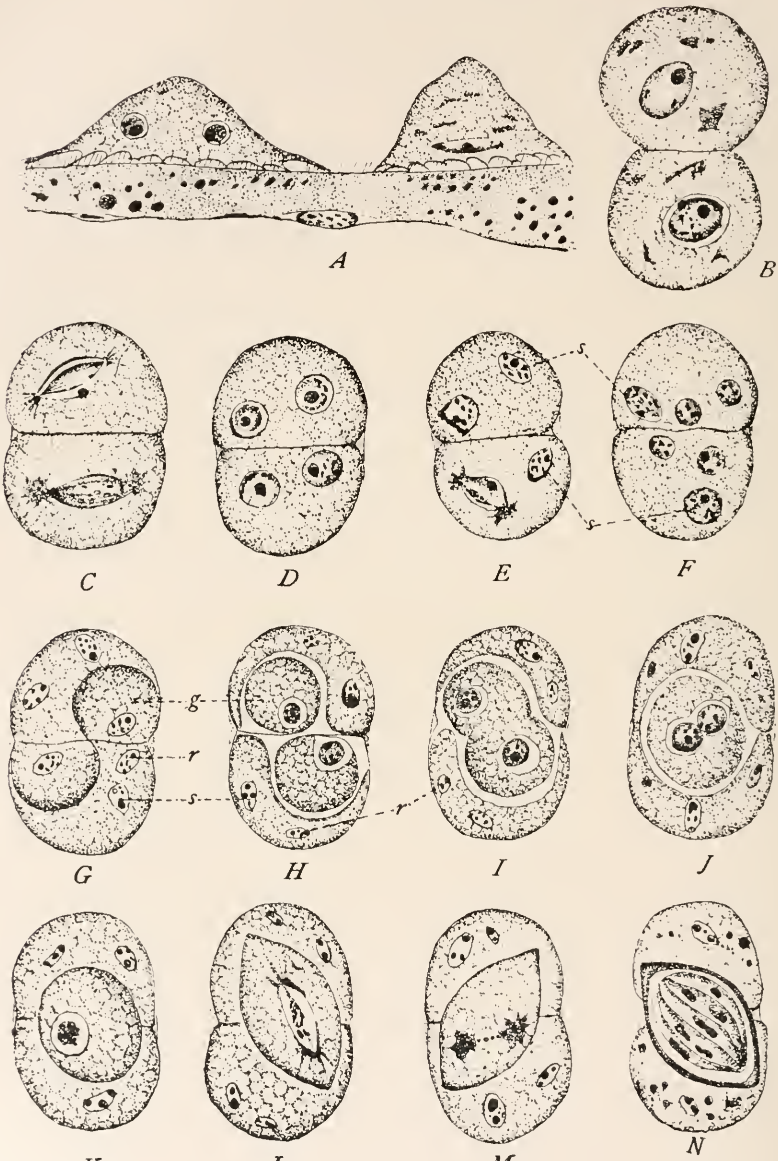


FIG. 12. *After Lèger.*

Protozoa. In the latter fertilization is accomplished by the formation and fusion of gametes or minute simulacra of the adult cells, some being differentiated into microgametes and macrogametes, or male and female.

In *Paramecium* there are no gametes of this kind, but portions of the adult individuals fuse as in *Ophryocystis mesnili*. Unlike this Gregarine, the fusion of the adult cells is only temporary and the two parties to the conjugation do not die. During the temporary fusion there is a mutual interchange of micronuclei and a mutual fertilization, while the only portion to disintegrate and die is the macronucleus of each conjugant, and this is replaced by a specially differentiated fragment of the new micronucleus.

In ciliated protozoa such as *Paramecium* and its near relations the germ plasm is concentrated in the micronucleus, while the somatic plasm is represented by the macronucleus. As we have seen, the micronucleus enlarges and divides during conjugation, first into two, then these into four, all but one of the four degenerating. The fourth divides for the third time, but this time unequally (Fig. 3) into a smaller migratory and a larger stationary form. The smaller micronucleus migrates into the other cell of the pair and there unites with the stationary larger nucleus. The macronucleus then degenerates and is absorbed in each of the conjugating cells.

The aberrant conditions in these Infusoria can be interpreted if we regard the three divisions of the micronucleus as the reminiscence of a

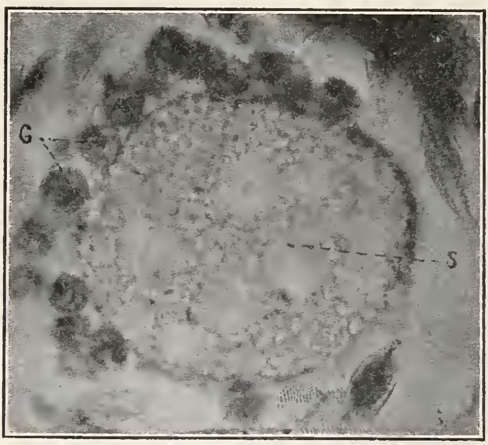


FIG. 13. *Original.*

process of gamete formation which obtained in remote ancestral forms. A parallel, but less extreme, case is seen in the Gregarine *Ophryocystis*, where one gamete only is formed by the conjugating cells. This is an isolated case among these Sporozoa, for in the typical forms a great number of gametes are developed, as shown in the accompanying photograph of *Monocystis* (Fig. 13). The one pair of gametes in *Ophryocystis*, plus the nuclear derivatives of the pro-conjugants, represent the swarm of gametes found in other Gregarines. Here, also, the internal or "nursed" condition of the gametes is a new development or adaptation.

Similarly in *Paramecium* the three divisions of the micronucleus may be interpreted as representing an ancestral brood of conjugating gametes, only two of which are now functional, the one representing a macrogamete or female form, the other a microgamete or male cell. Unlike *Ophryocystis*, the *Paramecium* individual does not become a nurse for the conjugating gametes, but remains, as before, the mechanism for the performance of the various physiological activities and the vehicle of the somatic and germ plasms.

The widely accepted view, therefore, as first formulated by Weismann and repeatedly stated in general works on biology, that Protozoa differ from Metazoa in having no equivalent of the somatic cells and therefore no somatic, or natural, death, must be abandoned. In the vast majority of Protozoa there is a clearly defined equivalent of somatic cells and an equivalent of natural death. The conditions in *Paramecium* and its allies are different from those of other protozoa, the old individual does not die at conjugation but is completely reorganized and built up of parts derived from the product of fertilization exactly as in Metazoa. The protozoon is not a potential germ cell, but like the metazoon is the carrier of the racial germ plasm which, in the great majority of protozoa is differentiated from the somatic plasm. As the germ cells of the metazoon become segregated into a germinal epithelium, becoming functional at maturity, so the germ plasm of the protozoon becomes segregated as chromidia or granules of a specific kind of chromatin, in the cell and is likewise functional at maturity.

ADAMAS: OR THE SYMMETRIES OF ISOMETRIC CRYSTALS

By Professor B. K. EMERSON

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THE number 3, the first to have a beginning, middle and end, has always been sacred. We are all trinitarians. Four is the second prominent number. It is the first square. The strong man stands four square to all the winds of fortune. The combination of these in the number 7 has always had a peculiar mythical significance.

The triangle with the eye in its center is the symbol of Freemasonry. And we may see how far this triangle will symbolize the three changeless and four variable solids which together constitute the seven crystal forms of the isometric system.

The triangle has three points which are unique and three and only three unique forms—the octahedron, cube and dodecahedron find place in the three corners of this triangle at *a, b* and *c* (as shown in the plate), forms made of eight triangles: of six squares, or twelve diamonds, and these numbers are twice the number three, or twice the number four or the product of three and four.

We may refer the planes of all crystals to three equal rectangular axes and only three permutations can be made from the only non-variable parameters 1 and x, viz., $1:1:1$ for the octahedron, $1:1:\infty$ for the dodecahedron, $1:\infty:\infty$ for the cube—and so we reach the same result algebraically.

The three corners of the triangle are joined by three lines, each line made of a series of points which should symbolize each a linear series of cognate forms, and we have these three forms in the trapezohedron *d,* the three-faced octahedron *e,* and the four-faced cube *f,* each linking by a single unbroken series the three corner forms. These are placed each on its proper line on the diagram. They are each twenty-four-sided figures. In two, each side is an isosceles triangle, in one, a trapezium, a combination of two isosceles triangles.

The three-faced octahedron starts as a 3×8-faced figure and ends as a 2×12-faced figure. The 4-faced cube starts as 2×12-faced form and ends as 4×6-faced form. The trapezohedren starts as a 4×6-faced form and ends as a 3×8-faced form, the three-faced octahedron with which we began. This is expressed algebraically by the three formulæ $1:1:m$, $1:m:m$, $1:m:\infty$, which have a single variable parameter, and no additional similar formulæ can exist.

There remains the space of the triangle made up of points arranged in two dimensions, or in lines connecting any of the forms represented by the previous positions or formulæ with the center of the triangle.

There is left a group of forms of a single type to occupy each point of this surface—the hexoctahedrons, and a sample of these is numbered *g* on the diagram. As the space has two dimensions this has two variables, $1:n:m$. The first group at the corners of the triangle had faces with like sides, the second at the sides of the triangle had faces with two like sides, this third and last group has faces with unlike sides; they are scaline triangles. They have forty-eight sides, a number that can factor into 24, 12, 8, 6, 4 and 3. As they are arranged over the surface of the triangle, these nearest the octahedron are six-faced octahedrons in appearance, those nearest the cube are eight-faced cubes, those nearest the trapezohedrons are two-faced trapezohedrons, and so on.

For many years I have shown this symmetrical passage of these seven forms into each other by using three colors, red for the octahedral lines, blue for the dodecahedral, and green for the cubical; a device my old pupil, Geo. H. Williams, used in his "Elements of Crystallography." The upper corner is all octahedral, the middle horizontal band is half so, the base not at all octahedral, and so of the other corners symmetrically.

The law of symmetry permits any symmetrical half of these faces to appear independently on the crystal, and the crystal fulfils the law of symmetry, and this may be done in three ways. (1) We may take all the faces in half the octants, or half the faces in each octant, and in the second case we may begin in the second octant (2) with the face adjacent to the initial face, or (3) with a face not adjacent. In accordance with the first law the half of the faces of the octahedron forms the tetrahedron which we naturally place in the figure, as (*h*) directly beneath the octahedron from which it is derived.

In the same way the tetragonal dodecahedron (*i*), the half form of the three-faced octahedron, and the trigonal dodecahedron (*j*), that of

the trapezahedron, are placed beside their parent forms, and the hexatetrahedron (*k*), the half form of the hexoctahedron, is placed necessarily above the latter, from its relation to the tetrahedron.

In accord with the second law, the four-faced cube gives rise to the pentagonal dodecahedron (*l*) which is placed above it, and the central figure, the hexoctahedron (*g*) gives rise to the diploid (*n*) which is placed naturally just above its associate the pentagonal dodecahedron.

There remains the single gyroidal form (*n*) obtained by the third law, which is placed directly beneath the central figure (*g*) from which it was derived.

An inspection of the figure will show that the triangle with which we began, the mason's symbol of the trinity, has most naturally developed itself into the form of a cross. Isolated on either side stand the cube and dodecahedron, two unique forms not capable of change or conversion into any other form, like the two thieves beside the cross. But said one of my friends, who is a good crystallographer, as I called her attention to this similitude, one of the thieves *was* converted.

This would seem to throw doubt on the record, I replied, and yet there are infinite possibilities present, as one sees, in the formulæ, $1:\infty:\infty$, $1:1:\infty$.

One observes next that the five Platonic forms find symmetrical place on the figure: two at the top, two at the lower corners and one—the icosahedron—by evenly balanced combination of the top and bottom of the figure. 111, $\frac{12x}{2}$.

The cross may be a cross of gold or of any other of the noble metals, and an inspection of the figure shows further that it culminates in an upper triangle placed like a crescent above the cross which contains the perfect forms attained by the perfect mineral, the diamond. At the center of this triangle is the tetrahedron (*h*) which gives the model of the atom of carbon and the hexatetradon (*k*) the most typical form of the diamond itself.

So again in a new arrangement of the elements in accord with the periodic law, proposed by the writer,[1] carbon is the culmination of the first octave and the very center and omphalos around which all the elements circle in their grand evolution. It has four-fold valence and threefold allotrophism and stands as the center of the seven elements of the first octant. And as the diamond is brought down from the heavens in the meteorites and brought up from the depths of the earth with the deepest rocks, and as it is endowed with the greatest power over light and over all solid bodies, so it presents in its almost spherical hexatetrahedron a mean around which the earth seems many times to have oscillated, as Arldt has shown,[2] now varying slightly toward the tetrahedron; now almost recovering again the spheroidal form.

[1] "Helix Chemica," *Am. Chem. Jour.*, Vol. XLV., p. 160, 1911.

[2] Dr. Theodor Arldt, "Die Entwickelung der Kontinente," Leipzig, 1907.

THE LACK OF PRINTING IN ANTIQUITY

By FREDERIC DREW BOND

AMONG fragments from the Græco-Roman world which have come down to us, not a few imply the use of some sort of stamping, or rudimentary printing. Seals and stamps bearing reverse legends are not infrequent, and, in 1908, the Italian Archeological Committee at work in Crete discovered a terra-cotta inscription whose letters had been impressed separately. According to Lacroix[1] Cicero had at least the idea of movable type, for in arguing against the Epicurean conception of the world as formed by the chance concourse of atoms, he uses this curious line of reasoning: "Why not believe, also, that by throwing together, indiscriminately, innumerable forms of letters of the alphabet, either in gold or in any other substance, one can print on the ground with these letters, the annals of Ennius?"

D'Israeli in his "Curiosities of Literature" has a quaint passage in which he suggests that the Roman Senate, fearing the effects of printed books, prevented movable type from coming into use. Another suggestion is that of De Quincey, who expresses the view, which he states he derives from Archbishop Whately, that the reason the Romans did not use the press was not from lack of knowledge of movable type but from lack of paper with which to make use of it. The ancients, as is well known, used not paper, but papyrus, on which to write. Shreds of this river plant (which, according to the Encyclopædia Britannica, still grows in the Nile valley) were split apart in long pieces, interwoven with one another and the whole then heavily pressed till a smooth and polished surface suitable for writing was obtained.

But though lack of paper might have impeded the development of typography in antiquity, had its invention, otherwise, been feasible, this does not seem to have been the main cause accounting for its absence. For, after the fall of Samarcand in 704, the Saracens became acquainted with the manufacture of paper and, also, no doubt, learned of block printing among the Chinese; yet printing did not appear in the caliphates of Arabia or of Spain any more than it did among the Romans. (Among the Chinese, needless to say, it was the multitude of written characters which prevented the development of typography from block printing.) It may be thus suspected that printing was wanting in the Roman Empire for much the same reasons that it was wanting among the Saracens. By the end of the first century of our era there were already written nearly all the works which we call classics and a num-

[1] "Arts in the Middle Ages," English translation, p. 486.

ber of each large enough to supply the reading demand had been turned out in manuscript. The literary output of new works in the Roman Empire was, from our modern standpoint, extraordinarily small. Aside from a few romances nothing existed in prose which would fall under our head of fiction. More than this, the output of scientific, descriptive and even historical writings was scanty in the extreme. Poetry, satire, philosophy and religion seem to have made up the greatest part of the output of new books in the Roman shops. Reading never became in the Roman Empire the necessity it has been to an educated man for many centuries past. Those who read habitually in the empire were the school children and scholars, and the wants of these last were supplied by the great libraries of Alexandria, Athens and Rome. Reading and writing were to others rarely more than a means of communication and of casting accounts or other commercial business.

Nevertheless, had printing been invented in the Roman Empire it would, no doubt, in the end, have created a demand for the books which it would almost certainly have called into being. Now the idea of typography, to nations possessing an alphabet, is so obvious that its failure to appear at all in Rome seems at first puzzling. Commercial enterprises are frequently started with no more prospect of gain than a printing office, if ready for work, would have faced in Rome. The real reason why in the conditions in the Roman Empire printing did not appear at all is revealed when we turn to the history of the early printers who invented the art in the fifteenth century. Though the idea of typography is obvious, the means first to make the idea actual were, we find, very far indeed from being so. Obscure though the early history of the art is, it is certain that effort after effort was made by several small groups of men in Holland and on the borders of Germany to make a commercial success of printing in the years between 1420 and 1450. The difficulties they encountered were manifold—a workable ink, a press which would give even impressions, but, most of all, type, both as regards its cutting or its casting and as regards its wear, we find giving them endless difficulties. We get some idea of the labors connected with the invention when we find Gutenburg trying to print at Strasburg as early as 1436. About 1442 he went to Mayence. There he exhausted his means in various experiments. In turn he took up and laid aside the different processes he had tried—xylography, movable types of cast iron, wood and lead. He invented new tools and experimented with a press made on the principle of a wine-press. He began work on nearly a dozen books and could finish none of them. In 1450 he entered into partnership with John Fust, a rich goldsmith of Mayence. Fust agreed to advance Gutenburg 800 gold florins for the manufacture of implements and tools and 300 for other expenses. In 1451 Peter Schoeffer, an employee in the establishment, at last hit on a commercially feasible method of casting type. This discovery, which enabled printing to become a business success, he communicated to Fust, and the two, after getting rid of Gutenburg by a legal device, then printed the famous "Great Bible" of 1456.

The story of the invention of printing thus shows clearly that without a strong money-making stimulus, the years of thought, labor and expense necessary to make a business success of the art would not have been hazarded. This money-making stimulus existed in the fifteenth century but was lacking in ancient times. The first printers came on the scene at the beginnings of the renaissance, when in Germany, where the awakening took a religious direction, there was a strong commercial demand for bibles and works of devotion, which was not supplied by the manuscript output. Moreover, eager readers for the literature of Greece and Rome and for the writings of the Church fathers could be found in every European country touched by the early Renaissance. This antique and religious literature and the bible, in the Vulgate and in translations, furnished the materials for the first printers till the controversies of the Reformation brought more grist to the mill. Between 1456 and 1478 the new art had been exercised in Germany, the Netherlands, Italy, France, Spain and Scandinavia. By the beginning of the sixteenth century it is computed that 16,000 editions of books had been printed.

On the other hand, in the Roman Empire, the popular old books were already in sufficiently large manuscript circulation and what there was of new material was amply cared for by the few publishing houses of Alexandria and Rome. In the Roman Empire the demand either for new books or for new copies of the old was too well supplied for inventor after inventor to take up some thirty-five years in perfecting movable type. It was the insight that the demand for more books would afford great gain if gratified which induced the long labors which ended in a practicable method of producing and using movable type. No such prospect existed in antiquity. To a Roman of the Empire a printing press would have seemed a commercially useless contrivance.

Whether, of course, fragmentary printing with some rude and easily produced sort of movable type, such as would be made of carved wood, ever occurred at all in ancient times can not be said. Not improbably, it did; the Cretan inscription, noticed above, had it been impressed on papyrus by ink, would have been an example of rudimentary typography. Possibly, for all we know, attempts of this sort, made for the amusement or for the novelty of the thing, may have occurred time and time again.

IS VEGETARIANISM CAPABLE OF WORLD-WIDE APPLICATION?

By Professor ALONZO ENGLEBERT TAYLOR

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VEGETARIANS are to be classed into four groups:

Vegetarians from motives of gustatory taste.

Vegetarians from motives of esthetic taste.

Vegetarians from motives of physiological opinion.

Vegetarians from motives of ethical opinion.

Some individuals, particularly in youth and in advanced years, dislike the flavor of flesh. Esthetic vegetarianism is common; and much that in the minds of the adherents of this exclusive diet is regarded as physiological opinion is really esthetic revulsion. The publication of the "Jungle" made many converts to vegetarianism. The centralization of slaughtering has intensified the natural aversion to the process, since, in addition to the lack of hygienic precautions that once prevailed in the large packing houses, the mass of gore as exemplified in the large establishments multiplies the esthetic revulsion. This is due to a trait in human nature familiar to every psychologist and sociologist. It has been difficult to arouse in this country a proper general appreciation of the extent of the yearly loss of life due to preventable dangers of machinery. The daily deaths among employees, here and there geographically, does not impress the public mind. But when through a defect of machinery a score of lives are obliterated in a wreck, the public is appalled.

Vegetarians from motives of supposed physiological opinion are very numerous. The physiological reasoning of the majority of these individuals is not based upon a study of physiology in any sense of the word. It is too often merely an expression of that license of democracy, according to which in this free country everybody feels the right to a definite opinion on every subject, without having studied it—a license almost as widely utilized by the college-bred as by the uneducated man, and contrary to common prejudice as widely utilized by men as by women. To the individual adherent of this school of vegetarianism, the exclusion of flesh from the diet is based upon the conviction that it is harmful to digestion or inimical to nutrition. A sense of personal experience (often purely esthetic, sometimes merely an idiosyncrasy, at times imaginary) is all too easily expanded into a generalization in the untrained mind. That the contrary experience can occur is made evident by the reported instance of a young man in the Alps who from childhood has lived solely on milk, excluding all meats, vegetables and fruits. The physiological vegetarian is usually inconsistent, in that milk, cheese, butter and eggs are not excluded, and very often meat stocks and animal fats are used in the cooking of vegetables. Reference will be made later to the physiological grounds upon which consistency in this matter is to be judged.

Philosophical vegetarianism rests upon the simple ethical proposition that man has no right to preserve his existence, enlarge his comforts or advance his material and spiritual welfare at the expense of the life of animals. Animals of all classes are to the ethical vegetarian, as in the Indian religion, as fully entitled to life as man; the commandment "Thou shalt not kill" is interpreted to apply generally to all types of animal life, and the slaughter of animals for the service of man is regarded as an expression of brute force which is inhuman. There is in this proposition an ethical appeal which finds response in every heart. The historical opinion of mankind, outside of India, holds that the right of man to kill animals is one vested in the higher moral and mental position of man among the animals, grounded in a higher importance in the broadest sense. The right to kill animals is, however, quite universally confined to instances in which higher human needs are positively and directly advanced. Needless killing is by all cultivated peoples condemned (if less consistently in practise than in theory) and the advance from savagery to civilization has been characterized by progressive cultivation of the regard for life. Our societies for the prevention of cruelty to animals and the Audubon societies are the public expressions of the ethical feeling that we owe it to animals, and to ourselves, to protect animals from suffering and from indiscriminate and purposeless slaughter. But deeply rooted in the minds of the mass of cultivated ethical men and women is the conviction that mankind has the right to be fed and clothed at the cost of the lives of animals; the domestication of animals is held almost universally to include the right of slaughter as well as the right of service.

To be consistent, the philosophical vegetarian must not only abjure the use of flesh in the diet, he must also abstain from the utilization of products of animal bodies, the procurement of which entails the death of the animal. Thus his articles of clothing, personal effects, household furnishings and implements of trade and occupation may bear no stain of blood. It is wholely inconsistent in one who keeps the hands and feet warm with the skin of an animal to reproach another for keeping the body warm by the use of meat as a fuel. Other fuels are truly available; so are other means for the retention of the heat of the body; the skin of man has no privilege above the other tissues of his body. The Indian soldier who refused to use ammunition greased with beef suet was entirely consistent. That it may be easy to feed the human body on food other than flesh and difficult to clothe the human feet without leather can have no bearing on the ethics or logic of the question. If man has the right to kill animals for his use, what is to constitute *necessary* use will always remain a matter of more or less individual judgment, as the movement for the protection of bird-life clearly illustrates. An aigrette may seem more necessary to the woman of fashion than are leather shoes to her less evolved peasant sister. From this point of consistency therefore no departure can be permitted. Here the consistent vegetarian and the consistent anti-vivisectionist meet, both resting the ultimate argument upon the broad proposition that man has not the right to nourish himself, clothe himself or save his life at the expense of the life of an animal. On the other hand, consistency does not demand of the ethical vegetarian, as of the physiological vegetarian, the exclusion of milk, cheese, butter and eggs from the diet. Although the slaughter of animals is from the ethical point of view condemned, the domestication of animals for their service is not excluded, since it can be easily shown that domestication yields to animals security from beasts of prey, protection from the elements and provision for food beyond the natural expectations, thus tending to prolong life as well as to promote the well-being of the animals. The ethical vegetarian is not concerned with physiological opinions bearing on the healthfulness of plant as against animal albumin, just as the consistent anti-vivisectionist is not concerned with the question whether vivisection has resulted in knowledge that leads to the alleviation of human suffering, the cure of human disease and the prolongation of human life; even though animal flesh be the most healthful of foods, even though vivisection lead to the cure of human disease, man has no right to these at the cost of animal life.

When now we turn to the modern science of nutrition, and ask the question: Is a vegetarian diet physiologically correct, adapted to the best purposes of a normal life, capable of sustaining the highest standards of growth, health, endurance and longevity? We receive a reply couched in no uncertain terms. Yes, a properly selected and prepared vegetarian diet meets completely the highest requirements of a diet. The technical reply to the question, stated in untechnical terms, would yield something like the following elucidation of the dynamics of nutrition. The three main classes of foodstuffs are sugars (including starches), fats and albumins, using the last word to correspond to what the physiologist terms protein. Since the fats and sugars, whose rôle is largely that of fuel, are interchangeable to a large extent, and since the vegetable fats are in every respect equivalent to the animal fats, the question of the adaptability of a vegetarian diet resolves itself into the concrete question whether plant albumin is the equivalent of animal albumin as tissue-builder. The chemical investigations into the constitution of albumins, carried out largely during the past two decades, have taught us that albumins are composed of simpler substances, termed amino-acids; the different native albumins are composed of many amino-acids in different proportions; and all the chief plant and animal albumins are in general composed of the same amino-acids, though in different proportions. These amino-acids we term the "building-stones" of albumin, and, as stated, the plant albumins contain all the essential amino-acids, the same building-stones that are contained in the animal albumins. When an albumin is digested, it is split (torn down) into the component building-stones. These building-stones are then absorbed, and with these the body, displaying a specific biological selection, builds or forms its own peculiar albumins. In other words, the building-stones are common to all albumins, the chemical and biological differences in the albumins rest in the architecture and not in the building-stones. Many types of houses may be constructed of brick of a common type; and so many kinds of albumin are formed of building-stones of common types; and from the common albumins of plants all the building-stones needed in the formation of the human albumins are to be obtained. It is clear therefore that it is quite immaterial to the human body whether it forms its tissue albumins from amino-acids derived from the digestion of animal or plant albumin, *i. e.*, these are equivalent in their nutritive values. These purely physiological and chemical data, abundantly sustained by laboratory researches and animal experimentation, confirm as well as elucidate the now widely made human experience that a properly selected and prepared vegetarian diet is a complete diet for all conditions and periods of life, beyond the lactation term of infancy.

Is a purely vegetarian diet better than a mixed diet, a diet containing a reasonable amount of albumin of animal origin? To make the question physiologically fair (since meats are often hugely overeaten), the ration of albumin in the two diets must be such as scientific investigations have shown to be sufficient and normal. Possibly a gram of albumin per kilo of body weight per day (equivalent to eleven ounces of meat per day for a body of 150 pounds) may be accepted as the normal total ration of albumin. There are absolutely no data of scientific nature or reliable observations in practical experience tending to show that either of these diets is in any way preferable physiologically to the other. It is apparently immaterial to the body of a hundred and fifty pounds whether in a properly selected and prepared diet the 2.2 ounces of albumin are exclusively of plant origin or partly derived from flesh. Since all cereals and vegetables contain albumin, a mixed diet always contains both plant and animal albumin, the ration of the latter of which would naturally run six to eight ounces of meat per day. I have used the words properly selected and prepared. It is obvious that the meats must be free of decomposition and properly cooked. It is on the other hand, possible for a vegetarian diet to disagree, if, as is often the case, the attempt is made to derive the larger part of the needed albumins from the legumins, peas and beans. For the vegetarian above all others, bread is the staff of life, and cereal albumin must remain the chief dependence of the consistent vegetarian.

Modern physiology then teaches that there is no demonstrable basis for the so-called physiological vegetarianism. It teaches further, however, that the assumed distinction, made for the convenience of arbitrary vegetarians, between the flesh of animals and the albuminous products of animals (milk, cheese and eggs) is unfounded. The casein of milk and the albumin of the egg are as distinctive and specific biologically as are the muscular tissues of the animals from which they are derived. Every reason advanced, or assumed to exist, opposed to the use of beef as albumin for the human diet must hold with equal force against the use of casein of the cow's milk; every argument against the breast of chicken must hold against the egg of chicken. As a matter of fact, as stated above, there is no physiologically valid argument against either beef or casein, against second joint or white of egg.

Since it is apparent that physiological vegetarianism is merely a scientific error and that vegetarians from gustatory taste or from esthetic considerations are merely instances of arbitrary individualism, ethical vegetarianism alone remains to be considered. This is in its tenets and conclusions a logical system. Is it susceptible of consistent, world-wide application? We will not attempt to discuss the large question as to man's relations, biologically and ethically, to the lower animals, concerning which the Christian and Buddhistic teachings are diametrically opposed. Assuming that the system were rigidly and consistently applied to the entire population of the earth, two main problems would be presented.

Is the production of plant albumin on the earth sufficient to meet the albumin needs of the earth's inhabitants?

What transformations would result in the customs, industry and commerce of the world, in the sociology and economics of the nations of the earth?

Before these two questions can be discussed, we must be clear as to exactly what would be demanded in the carrying out of consistent ethical vegetarianism. It would be permissible to domesticate animals, to employ them in service and to utilize the products of their life. It would not be permissible to kill animals either for food or for the products of their bodies. The use of milk, butter, cheese and eggs would be permitted; the utilization of fur and leather would be excluded. An exception might be claimed in the case of leather, that it would be permissible to use the pelts and hides of animals that had died of old age and of natural disease. Practically, however, this would be of little difference; the leather made from the hides of animals dead of old age would be of so low value as to be almost worthless; and the use of the hides of animals dead of disease, many forms of which are infectious and communicable to man, would be fraught with danger and difficult of execution. Mankind would have to face the problem of clothing without the aid of leather and fur.

Can the surface of the earth (for the fishes of the sea would have to be excluded) raise enough grain, fruits, nuts and vegetables, added to dairy products, to meet the albumin needs of the present earth's population? Unhesitatingly it may be stated that the area of the earth's surface now under cultivation could not, with the present methods of agriculture, dependably produce enough plant albumin to meet the needs of the present population. Very large areas of the earth's surface at present produce only grasses, shrubs and trees. Man can neither graze nor browse. At present these plants are consumed by cattle, goats, sheep and swine, whose albumin is utilized in turn by man. It is through the mediation of these animals that the vegetation of enormous areas of land is made available for mankind. At present probably one half of the albumin needs of mankind are met by animal albumin. To meet these needs with plant albumin and dairy products the world's production of grains and legumins would need to be doubled at the least. It is quite certain that this could not, with the uttermost efforts of the world's population, be dependably accomplished at present. It is possible that it might be accomplished, with the present methods on the present acreage of tillable soil, if no untoward manifestations of the elements occurred (such as severe winters, unseasonable frosts, floods, droughts, storms, excessive heat), with a dependable rain-fall in both time and space. But mankind would be yearly at the mercy of the elements. To meet fully and safely the needs of the growing population, four scientific advances of monumental magnitude would need to be attained.

The methods of the cultivation of the soil must be so intensified and revolutionized through scientific investigations as to make the yield of the soil less disproportional to its potential.

The conservation of water must be accomplished on a scale never before dreamed of.

The world-wide ravages of the parasitic diseases of plants must be checked.

The conversion of inert atmospheric nitrogen into potential soil nitrogen must be accomplished upon a vast scale through microbic and electro-chemical agencies.

The results of the accomplishment of these four advances, judged merely from present scientific knowledge of the possibilities in the four directions, would result in quadrupling the yield of the present area of cultivation, and in transferring to the state of cultivation vast tracts now untillable or even waste. The difficulties would not be technical, but human. To accomplish them the present intelligence of the human race, the dependable intelligence of the working race of mankind, would be wholly insufficient; the race has not attained to-day the scientific stature necessary to reach and pluck these fruits of knowledge. For the present, therefore, it is certain and beyond speculation that to place the human race upon the basis of ethical vegetarianism would be to expose the race to the mercy of nature, just as the vegetarian population of India is yearly at the mercy of the yield of grain.

To dispense with the products of animal bodies would be a task trivial in comparison with the problem of feeding. With wools, cottons, linens and the other plant fabrics, with metals and woods, all could be accomplished without great technical difficulties, were preconceptions once obliterated. From the standpoint of ethical vegetarianism, the wearing of fur, kid gloves and leather shoes constitutes fratricide. The number of animal and bird lives sacrificed to-day for purposes of superfluous comfort and for compliance with the vanities of fashion makes a striking numerical showing contrasted with the number of animals slaughtered for the supply of food. The difficulties would lie in clothing the extremities of out-door workmen; but the problem would be solved without difficulty in a world rich in inventive devices though poor in large scientific conceptions.

The results of the world-wide installation of vegetarianism to the sociological and economic institutions of the world need but to be sketched to be appreciated. The race of swine, as a domesticated family would be obliterated, and the number of cattle regulated by the requirements for dairy products. On the other hand, the number of horses would need to be augmented to meet the needs of enlarged agriculture; and the number of sheep to meet the increased demands for wool. The population of the world would tend to shift in latitude, and the commerce of the world would be revolutionized to meet the alterations in the currents and articles of trade. Fashions in dress and house furnishings would be strikingly changed. There is no need to dilate further upon these features. Man is to-day a beast of prey. Just as the whole map of biology would be changed in the day when "the lion and the lamb shall lie down together," so the whole face of civilization would be given transformed features in the time when man regards the animal as a brother and not as a prey. Man is a beast of prey because thus the preservation of existence is made easy; vegetarianism would make it difficult, and will therefore not be adopted. This carries its personal lesson: I, the vegetarian, must not be vain; because it is the meat-eating of my brother that makes vegetarianism possible to me.

A BUGBEAR OF ECONOMICS

By Professor HERBERT ADOLPHUS MILLER

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IT seems to be peculiarly difficult for men, whether in science, politics or religion, to give up a law or doctrine which has become a slogan to them, after it can no longer be justified. This is true of the law of diminishing returns which economists have considered to be fundamental to much of their reasoning. I have been able to find but one prominent economist of the present day who has made any definite attack upon this "law."

Simon N. Patten, in the "New Basis of Civilization" says:

> The law of diminishing returns was discovered by the most stupid body in England—a committee of the House of Lords. English agriculture at the close of the Napoleonic wars was so abnormal that any one could see how the high price of food brought poor land into cultivation. A committee, even if it was stupid, could not but stumble on the pertinent facts that formulated the law. But their perception of it does not account for its subsequent vogue. The real question of control is, Why did a nation, naturally optimistic and in a period of rapid industrial advance, accept the hopeless doctrine and permit it to curb their thinking for generations? Why also do teachers in America, where notoriously it never has been in operation, hold devoutly to it and spend their time expounding a lame philosophy to their classes?

Professor Patten does not follow this statement with a specific discussion as to his reasons, although his whole book is based on the principle of *increasing* returns.

I have looked through many books of modern writers on economics and find that all lay much emphasis on this law. The following are typical definitions from prominent economists. Seligman in his "Principles of Economics" says that "The law of diminishing returns is . . . the foundation of the law of rent. A farmer will some time reach a point where it will not pay him to add another laborer or another machine to his land because beyond the margin of profitable expenditure every additional 'dose' of capital or labor will mean a return insufficient to cover cost. . . . The law of diminishing returns is universal and applies to everything that possesses value." Professor Seager in his "Introduction to Economics" says, "After a certain point has been reached in the cultivation of an acre of land or exploitation of a mine increased applications of labor and capital yield less than proportionate returns in product, it being understood, of course, that no important change is made in the method of cultivation or exploitation." Carver in his "Distribution of Wealth" goes more into detail and proves the law with mathematical exactness. In fact, he is so clear that he seems to be proving the obvious. However, he offers as an excuse that such proof would not be needed "had not certain writers seen fit to deny it because it did not harmonize with their views of economics, and certain would-be reformers to ignore it because its recognition would interfere with the acceptance of their reforms."

Such a reformer, I suppose, he would call Wm. H. Allen, of New York, who said in a recent article in the *Annals of The American Academy* that "When John D. Rockefeller said to the world, 'There will never be enough money to do the world's uplift work,' he started in motion forces and doubts and compromises that will do vastly more harm to the south than the hookworm." The reason Mr. Rockefeller made such a statement was that he was biased by the law of diminishing returns which closes the door of hope, because, as Patten indicates, hopelessness is inherent in a world of diminishing returns. Many who argue for the truth of this law quote not only men of success like Mr. Rockefeller, but any business man or farmer who finds himself face to face with the law. The difficulty in both cases is that the individual is looking at production from his personal point of view, and not from the point of view of production as a whole. The economists, however, ought to see principles in the large.

Scientific laws are much like creeds. Some one has an insight which he formulates, and for him and some of his successors the formulation seems to satisfy the conditions and the needs. So an economic law is the classification of a group of facts as some one's insight sees them; but as with the creed, men may make the fatal mistake of thinking it an eternal truth. There was a time when belief in hell fire was an incentive to morality, but now many of us succeed in getting a degree of morality when in the state of mind of the small son of a famous modern philosopher who asked his mother what hell was. She described it to him and at the close added, "But there are some who do not believe this." The boy replied, "Mamma, I am one of those." There was a time when the law under discussion had a vital meaning to the race, but I am one of those who think that a new formulation is in place, that here is a case where orthodoxy does not mean clear thinking.

The fallacy common to Seligman, Seager, Carver and the others is that of emphasizing archaic conditions. Seligman, for example, was talking about equal "additional doses" of capital and labor; and Seager at the close of his definition said, "it being understood, of course, that no important change is made in the method of cultivation or exploitation." Now of what earthly good is a law for such conditions? If there is any indisputable fact in the world it is that important changes *are* being made in the methods of cultivation and exploitation, and as for *equal* "doses" of capital and labor, who is so simple as to think of adding them? The question is not that of adding another cartload of the old fertilizer to a wheat field, but of adding some new fertilizer, exactly fitted to the wants of the crop, by which it may be doubled in quantity. It is not a question of adding a man with a sickle, but of adding a man with a modern harvester; not of sowing the old seed to yield tenfold, but the new seed to yield an hundredfold. Capital is multiplying so rapidly that it worries some people, at least, to know what to "dose," and invention multiplies the units of labor so fast that they outstrip even our imagination. Now, to be sure, individual farmers must have practical methods of directing the expenditure of what capital and labor they have, and the law applies to them since an individual is more or less in an eddy, just as I am in the matter of capital. I have little more than I had before the last multiplication of the capital of the world, but I am not so personal as to deny the increase. I claim to be part of the age of airships, though I have never seen one, and am no nearer an automobile than a state of covetousness. I try not to be like the woman in a small town who came to me after a lecture in which I had said that, since three fourths of the women in that village bought their bread from bakeries where it was made by men, they could retain their power over bread making only by voting, she confidentially told me that she made her own bread, and hence did not see any need for women's voting. It seems to me that an economic law ought to be comprehensive enough to summarize the individual cases.

Professor Carver shows conclusively that in an individual case the law of diminishing returns may work exactly. He even shows that large-scale production does not overthrow the principle; but he does not consider the pertinent fact of modern industry, that invention, organization and efficiency make constantly changing conditions, and that "equal doses" are out of date. He admits that the law is more evident when applied to stationary civilization, saying, "*If* civilization should remain stationary while population increases in density there would be a smaller per capita production because of the law of diminishing returns. The terrible reality of this law is witnessed by the overcrowding of those populations where, as in the unchanging east, civilization has become stationary." I reply, "to be sure," but modern economics is neither history nor anthropology, and what should be taught in our colleges and to business men is a principle that applies to a progressive civilization. Again Carver says, "but with respect to the livelihood of a complex population considering all its industries in a mass, the operation of the law is not so clearly perceived."

Again I say, "to be sure," because under such conditions it is not operating. And at the end of his long chapter, considering the relative productiveness of different sorts of labor, he states, "that nothing could prevent its (the former of the cited classes of labor) declining relatively to that of the latter class except a radical change in the system of industry, which would call for more than a proportional increase in the former class." The contention of this article is that there has been this radical change in the system of industry, that increases are becoming more than proportional and that we are not yet even in sight of the beginning of the end. I am perfectly willing to admit that the law of diminishing returns has an illustrative value, but it is taught in many courses and economic articles as though the world in which we live were about to suffer from its "terrible reality" as it would in a world of stationary civilization. At a recent large gathering of economists there were but two expressed exceptions to the opinion that immigration was about to become dangerous because the additional numbers would make competition too keen. They thus implied the fear that this bugbear law of diminishing returns will soon deprive us of enough to eat. The whole difficulty is a mistaking of unjust and unequal distribution of wealth for an application of the law of diminishing returns. I presume that Mr. Rockefeller's difficulty arises from the fact that any other method of distribution than that which has been contributory to his own success is inconceivable. But economists ought to be able to see production and distribution at the same time and in their totality.

The law of diminishing returns is intimately related to another famous and equally archaic economic law, viz., Malthus's law of population. The substance of this law is that population tends to increase faster than the means of subsistence. There is something in this. It works in determining the number of wolves, but the last census report does not show *human* population in America confirming it. It is always a great satisfaction to find a single principle which will explain a condition; but we are becoming more and more convinced that social phenomena are the product of numerous forces and are not reducible to a single law. Malthus's law does not care whether a single family has many or few children, but whether population is increasing or decreasing. So the law of diminishing returns ought not to be limited to individual production, but extended to production as a whole. It is quite true that the surface of the earth is limited in extent, and that the population of the earth is multiplying; but it is likewise true that the sun is losing its heat, and that some time the earth will be uninhabitable. Any physicist might logically teach his classes the desirability that the human race accustom itself to the idea of being frozen out. But whatever the logic of the question, it would and should make very little impression on the average healthy-minded individual. Our problem presents a very similar situation in which we may justly question whether a healthy-minded person should have any fear about the exhaustion of the proper number of food units that may be required, even if he is as far sighted as a conservation congress.

Soon after Malthus had written his book, his theory fell into disrepute because of the opening of the great interior plain of the United States. But thinkers soon saw that the principle was just as true as before, though the pressure of conditions was temporarily postponed. But now that we have come practically to the end of free land we seem to be nearer than ever to the threshold of the catastrophe. Even such a good thinker as Joseph L. Lee, the Boston philanthropist, feels it, for in speaking about immigration he says:

> America is not infinitely large. It will in any case—in what, compared with the long future, must be regarded as a very short time—become so crowded that any further increase of the population—except at a comparatively slow rate can be made only at the cost of lowering the general standard of prosperity.

Land, however, is only one of the three factors in production. The incalculable additions to labor and capital in the last generation are so much greater contributions than more land could be that we are getting farther and farther away from, rather than nearer to, the catastrophe. To return to the analogy of the sun's heat: it is of course true that the sun can not continue to give off heat forever and remain as hot as before. But we have an interesting condition arising from the fact that though the sun is radiating its heat and thus diminishing its potential energy, yet the process of contraction which is taking place within the sun causes it to generate heat as rapidly as it is losing it, and while this is not a perpetual-motion machine, for the purposes of giving continuity of heat to the earth it is a perfectly satisfactory arrangement.

In like manner it makes no difference whether we get more land, or more productivity from the same land. Malthus found that population tended to multiply by geometrical progression, while the means of subsistence multiplied by arithmetical progression. This is true so long as the process is on an "equal dose" basis. But the conspicuous fact of modern times is that means of subsistence are multiplying at a rate which makes the multiplication of population look like the pace of the historic tortoise compared to that of Achilles, whom logic tried to keep from catching up. The logic of the law of diminishing returns is of the same type. Professor Carver shows that on a certain area of land twenty men can produce more per man than fifty, though the total production of the twenty men is but 380 bushels compared with 650 bushels produced by the fifty men. As a matter of fact, in spite of Zeno's logic we know that Achilles could overtake the tortoise, and we likewise know that the 650 bushels are being produced, and that everybody has more to eat than formerly. If pragmatism is justified anywhere it is in such considerations.

A farmer recently told me that his father paid for his farm, fifty years ago, by carrying the mail from Jackson to Grand Rapids, Mich., one hundred miles, taking just a week for the round trip. All the information he carried could now be transmitted by wire in three minutes and the increase in the amount now transmitted per man in the mail service per week is represented by a geometrical progression with a tremendous ratio. From this same farm his father hauled his wheat thirty-five miles to Jackson, taking approximately fifteen hundred pounds to the load, and requiring three days for the round trip. The Michigan Central freight can now transport wheat at least sixty thousand times faster; so that even though the most liberal division be made as to the part contributed by an equivalent of a single man and team now, a man's productivity is multiplied several thousand times. This is what we add instead of an "equal dose." It may be claimed, however, that the introduction of the railroad brought a period of phenomenal increasing returns, but that they were not maintained. It is a fact that there has not been an increase in speed at all in proportion to the outlay devoted to increasing speed, and the law of diminishing returns seems herein to be finely illustrated. However, increase in transportation does not mean simply increase in speed, but much more, it means number and extent of persons and things that can be transported in a given time. The number of people who have been brought into participation in transportation through the extension of the railroads, the increase in the power of locomotives, and the organization of the systems, demonstrates that the rate of progress has been continuous and of the same radical character as the change from stage-coach to express train. The exhibition of increasing returns is multifarious. During the Boer War I received the evening paper in an interior city at five thirty P.M. and read of battles that occurred at six o'clock that same afternoon in South Africa. This was in Tennessee near the home of Andrew Jackson who fought the battle of New Orleans after the war was over, and he did not then hear of peace until several weeks after it had been declared.

Increase in units of production does not consist merely of adding similar units. The saving of time by rapid transportation and intercommunication, the organization of capital so that it may be turned over several times where formerly it could perform but one service, makes a multiplication almost inconceivable, and every one knows that in the region of invention and organization we are just beginning to open up discoveries for entry; while the division of labor and the application of the processes of efficiency-engineering give a potentiality to the present units of labor that is revolutionary. If we will project our imagination, keeping within the limits of reason, we can predict the rate of progress will be continuous. It is quite conceivable that before this generation is passed we shall plough with power generated by the tides and transmitted by wireless processes, and that radium will be harnessed so that its incalculable energy can be used. With the tremendous increase in power the surface of the earth can be enlarged indefinitely. Why should not the plains of Europe and America be set on edge, or why should not artificial heat and light make possible several layers of productive soil, and certainly it can be employed all the year round! Already sanitation and invention are making possible the exploitation of the tropics, the really productive regions of the earth which hitherto have been undeveloped. Men can soon work where they can not live continuously because they can commute in airships and change climatic conditions daily.

In the light of these facts and fancies let us consider the validity of Malthus's three principles:

1. "Population is necessarily limited by the means of subsistence." This is more imaginative than dangerous, for, since "means of subsistence" is psychological as well as physical, it can not become a mathematical term. Nowadays our magazines are telling us that consumption of one half or one third of the "means of subsistence" would add greatly to our efficiency. I myself have made a definite reduction in the amount of food consumed and thereby multiplied my efficiency. Furthermore, it is undoubted that the science of nutrition is going to add many units to the food supply by subtracting the injurious, the wasted, and the unnecessary. This is the prospect before us, but in the meantime, with all the natural forces for multiplication of population active, nevertheless the means of subsistence has increased far beyond any proportions that have before prevailed. There is not the slightest evidence to-day that means of subsistence is directly effecting the increase in population.

2. "Population invariably increases where the means of subsistence increases, unless prevented by very powerful and obvious checks." This is so untrue to-day that it is not open to argument. In fact, the portion of population having the greatest means of subsistence is standing still while the poorest furnishes the greatest increase. To be sure, the standard of life may be the line at which the force of the means of subsistence is defined, but this is an artificial line. The rate of increase is not lessened by any powerful and obvious check, and it is not beginning to keep up with the rate of increase of the means of subsistence. There never was a time when the world was as well fed as at the present.

3. "These checks and the checks which repress the superior power of population and keep its effects on a level with the means of subsistence are all resolvable into moral restraint, vice and misery." Professor

Patten in his last book, "The Social Basis of Religion," says, "Sin is misery; misery is poverty; the antidote of poverty is income." If the signs of the times meant anything, there is an increase in the world's income and a potential decrease in the world's misery through better distribution. Misery, then, with its accompanying vice can not be the result of the law of diminishing returns, for returns are increasing.

Since the means of production are land, labor and capital, and the methods of capitalistic-mechanical production increase the possibilities of the last two indefinitely, the resources of production show no more signs of being exhausted than the heat of the sun. Our census returns show that the population of the United States has increased 21 per cent. in the last decade, that urban population has increased even more, and that many of the best rural districts have lost population; and still there has been a disproportionate increase in the amount and variety of food. These facts make it absurd to argue that, as applied to production in the large, the law of diminishing returns is a factor to be considered. Why then in the teaching of economics, and in business is not the emphasis changed so that such a point of view as that of Mr. Rockefeller may not be attained? For obviously, as Patten says, our modern progressive civilization has passed the line of deficit and is capturing broader and broader fields of surplus. If we are going to retain a full treatment of this law and Malthusianism in our text-books, could it not be labeled as a historical condition of which occasional relics may still be found? In answer to the argument that it is essential that we take the law as a starting point for the explanation of economic phenomena, I would reply that the explanation is good only for a condition that is stationary and looks to the past. May we not demand that in some way economists should frame a law, in which, as in the law of the moving point by which the hyperbola is traced, the prophecy of the future should be as perfectly expressed as the history of the past, and thus looking ahead, give us a true description of modern conditions of production?

THE GERMANS AT SCHOOL

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AT the time of their political weakness the Germans were derisively called the thinkers and dreamers. When the other great nations divided the world of reality among themselves, the Germans took refuge in the realm of fancy. The stronger peoples considered them as the members of a rich household look on the poor schoolmaster at their table. That time has passed away. The politics and commerce and industry of Germany have secured its powerful position in the world, and no one doubts the strength of the Germans in the field of the real facts. But there was mingled with the derisive mood of previous times a silent respect for that German idealism. The name of thinkers and dreamers appeared to some, and not to the worst, a title of honor. The world acknowledged that in scholarship and research and education the Germans were able to teach mankind. Their schools were models and their methods superior, and in the days of war the world accepted the saying that the German schoolmaster had won the battles. How much of this honor and glory has been left in these days of German commercial, industrial and political advance? Has the forward striving in the realm of might and power meant loss of prestige, and, what is more important, loss of true achievement in the field of thought and education, or did the progress of modern Germany involve as much intellectual gain as practical profit? The Germans at work easily win the admiration of every visitor who goes to their centers of industry. Are the Germans at school equally deserving of honorable praise, or are they simply resting on their laurels?

The educational life of a country is always a great organism in which all parts are interdependent. There can not be good schools without good universities, nor good universities without good schools. The quality of the teachers and the quality of the pupils, the general education and the special instruction are all intimately related to one another. We must look into this organic system if we want to ascertain its strength and endurance. A few educational show pieces are not enough. Is there progress and growth in all the essential parts. We may begin with the German university, which is, after all, the real heart of the whole organism and which had more direct influence on American educational life than any other part of the German educational system. Those who built up the great American institutions in the last generation from mere colleges into true universities had received the decisive impulses in German academic halls. To be sure in recent years a kind of reaction has set in in America. The tradition that German university work represents the highest standards of scholarship has recently been roughly handled by skeptics. Some have claimed that German university research is too specialistic and on that account too narrow. The German scholars lack the wide perspective which has been characteristic of so much of the best English work. Others insist that the structure of the German publications is formless. They long for the French polish and clearness. Some blame the German professors for a certain remoteness from life and feel that American scholarship will abolish this kind of "scholarship for scholars" and will again unite science and life. It was inevitable that such a reaction should occur. The young generation of American university instructors found a situation entirely different from that which their teachers had found some decades before. Great American universities had been built up in the meantime and had created a new spirit of scholarly independence which naturally took the turn of a slight opposition to the former masters. But such reactions are only passing moods. Those who know German scholarship to-day have no doubt that all these accusations never have had less justice than at present. Certainly German scholarship is specialistic, and there will never be any true scholarship which is not founded on specialistic work. Any thorough research must be specialistic, and research without thoroughness can never secure lasting results. But the work of the great German naturalists and historians has shown at all times the tendency to wide generalizations, and the present day perhaps more than the last half century is again filled with broad philosophical endeavor. Still more unfair is the often repeated cry against the formlessness of German scholarship. Not every doctor's thesis can be a thing of beauty, but perhaps there has never been a time in which the German language has been so shaped by aesthetic ideals. The German bookbinders were for a long while notorious for tasteless covers, but the general opinion in recent international exhibitions has been that now no country makes more beautiful bindings than Germany. This artistic improvement of the book is not confined to the cover. The content of the German book shows a literary finish in structure and style which ought not to be overlooked. Finally, as to the aloofness of German scholarship, the triumphs of modern German technique and medical therapy speak loudly enough of the comradeship between science and life. And how could it be otherwise in a country which has become so mark-hunting and practical. The best proof of the injustice of such accusations and attacks lies in the number of American students who still feel attracted by the German academic atmosphere in spite of the wonderful development of American higher institutions of learning.

Last winter there were three hundred American students in German universities, and it must not be forgotten that these young men and women are not undergraduate college students, but that the German university welcomes them only if they can show their college diploma. The German semesters correspond to the study in the post-graduate departments of the American universities. As Director of the Amerika-Institut, I wrote to these three hundred delegates of the new world and asked them with what training they came and for what purpose, whether they felt satisfied or whether they found anything of which to complain, what they were doing and what they were intending to do, and what they could suggest. The answers display an interesting variety. The young American scholars came from all parts of the country and their favorite spots in Germany are Berlin, Leipzig, Munich, Heidelberg and Göttingen. In their studies naturally the German language and German literature take the lead, but philosophy, history, political economy and, in the line of science, chemistry and medicine stand next. Mathematics is also often chosen, and, on the whole, there is no corner in the field of learning to which some Americans are not turning. Lowest in the list is the study of law, which of course is best pursued in one's own country. As to their aims and reasons for coming to Germany, some, to be sure, had no deeper argument than that they "had a fellowship," and some that there "is no special reason." Some wanted to see a foreign civilization at first-hand in order to be able to judge more correctly of their own, or to study German in order to teach it in America. But the overwhelming majority insisted that there was still superior opportunity for their special branches in German institutions and that the most thorough and deepest preparation could still be gained on German soil. The two fundamental tones of the replies were given by the one who wrote: "I came to train myself to think independently," and by the other who wrote: "The best that was offered me in the American lecture room, library and seminary was the fruit directly or indirectly of German research. I wished to come into intimate contact with it." As to their satisfaction with the results, praise and complaint were intermingled. Many asserted that they were entirely satisfied, not a few expressing themselves in terms of enthusiasm. Some limited their approval to certain sides: "Very well satisfied with intellectual side of the university, but have not received much help religiously." Others miss the American sports or the social life among students. Many are dissatisfied with the lack of personal contact with professors. Again some complain that the student finds no oversight and is not called to account and that accordingly too much loafing is possible. Some complain that the attendants do not understand English or that the libraries do not give out the books quickly enough. Some suggest more opportunities for learning the language, others demand the removal of evil social influences and student drunkenness. But there is an almost surprising unity in the instinctive acknowledgment of the admirable methods of research and of highly advanced instruction. This cordial appreciation by those who stand in the midst of the German influences corresponds to the judgment of all who see German academic life with impartial eyes. There is an intensity in the search for truth and an eagerness for the development of the best scholarly methods which is still unsurpassed in the world.

The weaknesses of the German university are not few. To those who come from American traditions the most regrettable difference is the lack of interest in the student's life. The student is practically left to himself. This is true as to his social life and true as to his studies. No one supervises him, no one cares whether he is industrious or lazy, and the result is that many a weak man comes to grief who might have succeeded with the help and control of the American system. But these defects of the German university as educational institutions are the necessary counterparts of their excellencies as places of independent scholarship. The highest goal of intellectual achievement will always be reached only in complete freedom, and this freedom is somewhat dangerous for the weak man. There can be no doubt that the German system is indeed much more adjusted to those above the average than to those below, and the opposite is true of the American system. But it is not only the lack of personal help and the demand for his own activity which is in contrast with the American ample provisions for intellectual support. Even the choice of the teachers differs in the same direction. The American instructor is appointed, above all, because he is a good teacher; the German because he is an important contributor to the advancement of knowledge. He may be and not seldom is a poor teacher. Yet the German university ideal suggests that the true student will profit more from the contact with a man who has mastered the method of research than with any inferior scholar, however effective he may be as a teacher. The American is often no less surprised by the way in which the professors are chosen for appointment. The American universities are monarchies. The president with his trustees elects a new member of the faculty without being dependent upon the vote of any professor. In the democratic life of the German university the government which has to make the appointments is dependent upon the vote of the faculty itself. The professors choose their own colleagues. This again in principle indicates the desire to make the point of view of scholarship superior to every administrative question. It can not be denied that in practise it frequently looks quite differently. The influence of the colleagues is too often exerted in the interest of some groups, cliques and petty prejudices. It would be a blessing for many a university faculty in Germany if an American president with his great powers stood above them. The Germans themselves are far from considering their universities perfect. Intense reform movements are reshaping the entire university life, but it is characteristic that no so-called reform propositions are taking hold which limit in any way the freedom of study. The Germans do not want more examinations by which the student becomes more or less a school pupil, although they believe in thorough discipline and supervision even in the highest classes of the Gymnasium, which corresponds to the average American college. The most wholesome change in the student life is the quiet but steady repression of the vulgar beer-drinking habits with all the noisy accessories. The entire student life has become cleaner and more modern. The old traditions had come from a time when the young academic scholar wanted to emphasize the contrast between his eager life and the dullness of the philistine crowd. But modern times have changed this contrast by bringing life and interest and political activity into those crowds and the student has thus lost his right to live a life entirely different from that of his social surroundings. The rush of young Germany toward the university is still steadily increasing. There are about 63,000 students in the twenty-one high seats of learning, 12,000 in the law schools, 12,000 in the medical schools, about 4,000 students of divinity and the remainder in the so-called philosophical faculty which corresponds to the American graduate school. It is characteristic that the chief increase has come to the universities in the large cities in which the old-fashioned student life has always played a small rôle. In Berlin there are 14,000 persons attending the lectures and in Munich 7,000, in Leipzig 6,000. Yet especially those universities in small towns which are famous for the beauty of landscape have had their proportionate growth. In lovely Freiburg in Baden the one thousandth student was welcomed with a celebration at the time when I came there as a young instructor. Recently they have celebrated the coming of the three thousandth student. The rapid growth of the academic communities strongly suggests the foundation of new universities. Münster in Westphalia grew into a full-fledged university only a few years ago, Frankfort-on-Main is at present fighting with enthusiasm for the development of its academy into a university. The Prussian Diet is still seriously objecting to this ambition of the citizens of Frankfort, as it fears that the smaller universities in the neighborhood would be the sufferers, but the university of Frankfort is surely to come. The same may be said of the university of Hamburg, which so far consists of a number of interrelated institutes. But while the universities are growing in number and branching off in new and ever new specialties, they are also being supplemented by new forms of scholarly activity. The most characteristic new feature which gains increasing importance is the erection of research institutes, especially in the field of natural science and medicine. There investigations can be carried on without any reference to instruction, the scholars are disburdened from every educational responsibility, and the progress of knowledge becomes the only goal. At the same time the number of technical schools on the level of the universities has been increased to twelve, since those of Danzig and Breslau have recently come into existence, and Germany's famous mining schools, forest schools, agricultural schools and veterinary schools show the same signs of flourishing life.

The greatest change, however, in the academic life of the nation has come through the new regulations which link the university with the schools. The American schools have usually left a certain freedom in the choice of studies within a single institution. In the same high school the boy can take a classical course or a more realistic course. Germany has always had separate schools for the different schemes of preparation. The higher schools which engaged the boys to the nineteenth or twentieth year have always been of three types, the Gymnasium which puts the chief emphasis on Latin and Greek, the Real gymnasium which omits the Greek and emphasizes modern languages and the Oberreal gymnasium which has very little Latin but much natural science. They correspond roughly to the American high school and a modest American college or the first two or three years of the best colleges. The tradition allowed only those who had the certificate of the Gymnasium to take up the study of law, medicine, divinity and philology. The university study of natural sciences and of modern languages besides a number of practical callings were the only goals accessible to those who came from the other two types of schools. Long struggles which excited all Germany led to the abolition of this monopoly by classical education. With the year 1902 the great modern school reform began and every year has brought new advance. To-day practically every boy who has passed through a school of any one of the three types finds the doors of the university wide open, whatever profession he may choose. It may be too early to judge whether only advantages will follow in the train of this reform. There are not a few who are afraid that the realistic schooling of the future lawyers and government officers may be a danger for the idealistic character of the national life, and there are many who believe that even the physician needs to read his Plato in school time more than to begin at once with the chemical laboratory. But in any case the great change has brought fresh air into the academic halls. The second great change was the full admission of women. For a long time they had the permission to attend lectures but no academic rights equal to those of men could be acknowledged for the women students until they should bring to the entrance door of the university the same certificate as the boys were expected to bring from their schools. The real advance of the women in the university sphere depended upon the establishment of girls' schools which would lead to exactly the same goal as the Gymnasium for boys. This was at last accomplished by the splendid organization of girls' instruction of three years ago.

Prussia has now four types of higher schools for girls, each of which may be divided into various independent departments. In the center stands the upper girls' school, a somewhat revised edition of the traditional German school for girls. There are ten classes which are usually passed through in the period from the sixth to the sixteenth year. The first three classes are preparatory, with eight to ten hours a week instruction in the mother tongue, three hours arithmetic every week, two to three hours writing, two hours needlework, three hours of religion, which is an organic part of every German school, two half hours of singing, two half hours of gymnastics and some drawing as well. In the seven upper classes the German language takes six, five and finally four hours a week, and French exactly the same number, altogether thirty-two hours each in those seven years. English is taught in the four upper classes only four hours a week, mathematics three hours a week throughout, geography two hours through the seven years, natural history two hours, religion two hours, drawing two hours, singing two hours, gymnastic two hours, needlework two hours, but this is no longer obligatory in the four upper classes. Those who have passed through this ten years' course may enter either the so-called Frauenschule or the Seminary or the Studienanstalt. The first is planned to complete the education of a young woman who seeks a higher training without any professional aim. It is adjusted to the needs of women who are to play an intelligent rôle, not only in the home, but also in social life. It is in no way a finishing school for one who aims to shine in society, but meant for those who really want to serve. It is usually a course of two years in which pedagogy, household economy, kindergarten work, hygiene, political economy, civics, bookkeeping and needlework stand in the foreground, while modern languages, history, literature, natural science, art, drawing and music are relegated to the position of minor electives. The Seminary, on the other hand, is meant for those who aim to become teachers of the lower schools. It demands three years' scholarly work and one year of practical training in schools. In those three years of theoretical study, French, English and mathematics take four hours a week each year, German, natural science and religion three hours a week, pedagogy, history and geography two hours. In their fourth year, the practical term, the candidates study pedagogy and methods of teaching seven hours, eight hours a week thesis writing, six hours training in practical class work and six hours training in the practical methods of the various subjects, including laboratory experiments. In addition to all this, through the four years there are three hours of gymnastics, two hours of drawing and one hour of singing. For the friends of women's progress, however, the chief accent of the system lies on the Studienanstalt. It is a school of six classes demanding six years' work open to those who have passed the first seven classes of the higher girls' schools. The three highest classes of the girls' school are then skipped, and instead of them the six years' course undertaken. This, however, is again divided into three separate schools corresponding to the Gymnasium, the Real gymnasium and the Oberrealschule of the boys. In the Gymnasium course during those six years the girls have three hours a week German, six hours a week Latin, at first three, later two hours French, in the first two classes three hours a week English, in the last four classes eight hours a week Greek. Through all the years there is history two hours, mathematics first four, later two hours, religion two, geography one, gymnastics three and drawing three. In the Real gymnasium the girls have no Greek whatever, but throughout six hours Latin, three hours French, three hours English and somewhat more mathematics and natural science than in the Gymnasium course. Finally in the Oberrealschule Latin too is omitted while both French and English are increased to four hours a week, mathematics to five, natural science to four and German also to four. This new plan adapts itself most successfully to the various needs, and the only danger lies in the fact that inasmuch as these three last types of schools open wide the way to the professional studies of the universities the number of academically trained women may soon by far surpass the demand of the community.

This vivid activity in the direction of liberal changes through governmental initiative does not exclude an abundance of efforts to break new educational paths. For instance much interest is centered nowadays on the so-called reform schools. They aim toward postponing the decision for a particular type of school as late as possible. The usual schools are different from the start. The classical schools begin with their Latin in the lowest classes. The reform school systems, of which the model was the city school system of Frankfort, have a common foundation for all schools, reminding one in this respect of the American principle. The much-discussed Frankfort plan in the first three classes gives to all the pupils in common five hours German, six hours French, two hours geography, five hours mathematics, two hours of natural science, two hours of writing, three to two hours of religion, three hours of gymnastics, two hours of drawing and two hours of singing. Only with the fourth class does the bifurcation begin. In the classical course the fourth class begins at once with ten hours Latin and the sixth class with eight hours of Greek, while in the realistic course the Latin is started in the fourth class, with eight hours going down to six, and the English begins in the sixth class with six hours.

There is still much distrust of this apparently very reasonable procedure. Every one feels that the momentous decision of the character of the education ought to be made at an age when the individual differences show more clearly than in the first years of school life, but the friends of the traditional Gymnasium are still convinced that a thorough classical training in accordance with the old German ideals ought to shape the mind of the youth in the characteristic way from a tender age. There the German school men still stand in the midst of passionate discussions.

But the intense pedagogical forward movement of the German people must not be studied only in the programs of the official schools. After all they represent the conservative aspect. The most progressive changes which would upset the traditions altogether are expressed in private institutions, usually the creations of enthusiastic idealists. They feel that there is a deep-lying antagonism between the claims of the official school and hundreds of thousands of hopes. Undoubtedly a large part of the nation is convinced that the whole school system is antiquated and too little adjusted to the needs of the new Germany. The schools still carry with them too much of that Germany which lived and thought but which was politically powerless and in the practical world helpless. The new German who does not look into the clouds but prefers to stand with both feet firm on the ground wants knowledge of natural science instead of languages, wants development toward national patriotism instead of religion in school, and wants civics instead of archeology. The center of it all is the firm demand that the youth be prepared for the national life with its social demands and its realistic energies. The character is to be developed still more than the intellect, and the mind is to be schooled for a time which overstrains a man unless he is trained for concentration. Of course much superficiality and pedagogical amateurishness are in play there. Especially the educational value of the natural sciences is still a very doubtful claim in the eyes of those who have really watched the outcome. But in this point too the serious reformers propose a fundamental change. They say that natural sciences are indeed without fundamental significance for the mind of the youth if the instruction means only a heaping up of information. In these days of rapid naturalistic progress the temptation is always great to bring the boy in contact with as many fields of positive knowledge as possible. But there is too much kaleidoscopic unrest in this superficial excitement of the intellect to bring any lasting gain. The new leaders therefore wish that knowledge be considered as unimportant and that the mastery of method and of naturalistic thinking alone be emphasized. The boys are to learn how to learn from nature. And in a corresponding way these groups of reformers wish to change the teaching of history. The children are not to learn the facts but the methods to find out the true facts from various sources. They are to be brought into contact with the old reports by which the events of the past are transmitted. The knowledge of the languages ought to be gained by practise in conversation, the knowledge of the earth by wandering and living in nature.

This is typically combined in the much-admired institutions of Dr. Lietz, the so-called Landerziehungsheime, educational homes in the country. Lietz was a young enthusiastic teacher who was moved by the ideal of building up healthy, strong, joyful, energetic and judicial men who would be in sympathy with their fellow creatures and understand the needs of the common people, and yet who would be inspired by art and science and technique. He has created in the loveliest regions of Germany three national schools, for the youngest children between seven and twelve in Ilsenburg in the Hartz, the second in Haubinda in Thuringia for the boys between twelve and fifteen and the third in the castle of Bieberstein in the Rhön Mountains for boys between sixteen and twenty. All three places are far removed from the turmoil of the world, and the boys find there a most harmonious interconnection of intellectual training, handicraft work, agricultural activity, sport and inspiring social intercourse between teachers and pupils. It is a delight to see those happy youngsters under conditions in which their natural instincts for out-of-door life and for social companionship, for manual activity and for sport, are so wholesomely satisfied and at the same time where their intellectual development is secured by individualizing training in scholarly method. They learn really to love the literature and the history of their country and to become personally interested in the political and the economic structure of their nation. Their minds are opened to music and art, to religion and morality. Small groups of them undertake walking trips not only into the near neighborhood, but to far-distant parts of the fatherland in a simple camping style. Sometimes even long journeys to Egypt and elsewhere have been undertaken in the vacation time. Truly it is an ideal method to develop a healthy mind in a healthy body. Whether it will become the crystallization point for general educational changes in Germany is, however, more than doubtful. So far these reforms are in an uphill fight. They suffer from that which they feel as an unfairness, namely, from the fact that their schools must lead the boys to the same examinations which the regular school boys have to pass if the pupils are to go over to the university or to any other official career. This demands that in the last years much cramming be introduced and that features be forced on these new boy paradises which seem very foreign to their spirit. They demand, accordingly, new regulations which will give to the new types of schools more appropriate examinations as end points. As long as this is not granted, these schools remain confined to narrow circles. But more important perhaps is the second fact. The Germans feel on the whole very unwilling to give their sons and daughters out of the house, if the education can possibly be obtained in the neighborhood. The system of the American academies and boarding schools is contrary to all German traditions. Especially in the large cities in which the Americans are most readily inclined to send their children away for the educational years, the Germans would least think of separating the youth from the home.

It may seem surprising to American observers that in the abundance of educational schemes which recent times have ripened in Germany nowhere has a serious movement toward coeducation been started. In a very modest way it has been forced on the communities in those places in which girls want to be prepared for the university but where no special Gymnasium classes for girls have been arranged. Just these exceptional cases however hasten the establishment of special Gymnasiums for women. The German community is decidedly unwilling to gather in one schoolroom boys and girls beyond the age of the elementary school. They do not object to the coeducational instruction of small children in rural schools. This is a frequent practise. Nor do they object to the comradeship of young men and women on the level of the highest university work. But in the broad period of the development of adolescence they believe in strict bieducation. Even when the material of study is the same, differentiation of method is demanded and German pedagogues decidedly object to women teachers for grown-up boys. The fact is that the new girls' school plans, even where they lead to exactly the same goal as the Gymnasium or the Realschule, distribute the material in a characteristically different way from the program of the boys' schools. They acknowledge the psychological laws of the different rhythm of the development of the two sexes. The well-known suggestion that the boys become refined and the girls strengthened through the presence of the other sex is the more powerless since the educators feel justified in reporting that even America, where the experiment has been tried most extensively, is in a stage of reaction against the coeducational enthusiasm.

Whoever looks at the free play of educational energies in Germany's social organism is probably most impressed by the strong activity outside of the regular day schools. Instruction for those who go to school because they have not yet entered a practical life work is furnished everywhere in the world, but no country shows such systematic educational planning for those who have left school and are at work in business or in factories, in agriculture or in any other calling. The splendid development which this type of pedagogical influence has found in recent times has been to a high degree due to a reaction against grave misuses in the past. In early times, to be sure, the boy who left the primary school was under the strict control of the master in the workshop or in the business. But the nineteenth century changed those paternalizing conditions and brought complete freedom. The result was a steadily growing insubordination and obstinacy, frivolous breaches of contracts and unreliability, together with a craving for enjoyment on the moral side, and a lack of careful training on the professional side. The community felt this inability to get hold of the boys who had left school as one of the most serious national dangers. In response to this need the continuation schools were founded which are to develop the youth after the school years in moral, practical and intellectual respects. The essential difference from all other schools lies of course in the fact that these take only a fraction of the boy's time in order not to interfere with his work. But they receive their real social background by the legal obligation of the employer to give to every boy the opportunity to attend these school classes. Compared with the general elementary school, the continuation school is professional, while the other is a humanistic school. On the other hand, compared with the real technical schools both lower and higher, it combines the technical instruction with general education. But, above all, the technical schools demand for some years the whole working time of the pupils, while the continuation schools are only supplementary to the chief business of the boy. The technical schools, such as for instance all the agricultural schools or the special industrial schools or the commercial schools, are strictly professional; the continuation schools are essentially educational. It may be said that even the technical element in them becomes subordinated to the aim of making a whole man and not only a skilful worker out of the boy who has left the school in his fourteenth year. The principle of this continuation school has conquered all Germany, but the realization of it looks very different in the various parts of the country. In some, the communities are forced by law to establish such schools, in other parts the towns are free to arrange them according to the local needs. On the whole this difference seems less important, as the continuation schools are flourishing wonderfully in some parts in which the laws give large freedom in the matter to the community. The point about which the discussion at present seems much more excited is the question whether the school teacher or the man of practical life, the master in the arts and crafts, the business man, the farmer, the industrial specialist, is to be the decisive factor. The men of the workshop complain that these schools become worthless as soon as the methods and the points of view of the school teacher control them, and the opposite party believes that the highest value is missed if the spirit of the factory and not that of the schoolroom enters into them.

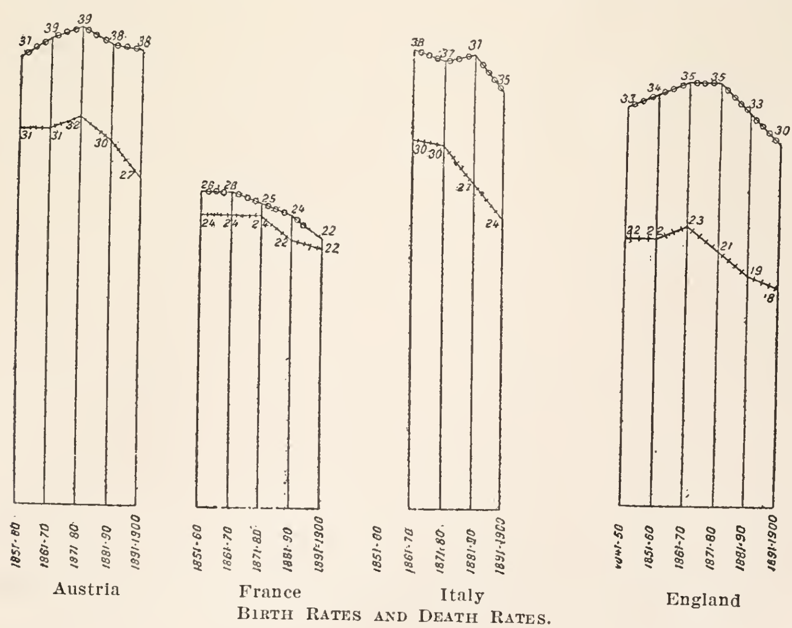
As the continuation schools were to serve the needs of young people in many different walks of practical life, the schools themselves had to develop an almost unlimited manifoldness. A subtle adjustment to the local conditions as well as to the varieties of industry and trade had to be aimed at. Continuation schools for candy makers and continuation schools for shoe makers had to be different. There are five chief types: the general continuation school, the commercial, the industrial, the rural and, exclusively for girls, the household economy school. Each of these types is realized sometimes in schools of obligatory character, and sometimes in schools where the attendance is voluntary, as well as in schools with prescribed courses, and in others with great freedom of election. The most famous system of continuation schools, the discussion of which has had most valuable influence on the whole German situation, is that of the city of Munich, where the indefatigable superintendent of schools, Dr. Kerschensteiner, has succeeded in a perfect adjustment of educational needs to the practical requirements of the community. Particularly his industrial continuation schools have been organized in such a way that almost every important business is represented by special classes for apprentices and special classes for journeymen and older working men. There are classes for chimney sweepers and for cabinetmakers, for coachmen and for ivory carvers, for watchmakers and for photographers, for tailors and for locksmiths, for barbers and for gardeners, for office boys and for waiters. There are altogether two hundred and ninety-six classes for the first years and one hundred and thirteen classes for those who are beyond the years of apprenticeship. About ten thousand boys are regularly attending. Every class has a careful program in which elements of general human education, elements of technical theoretical information and technical practical training, and finally elements of civic and sociological instruction, are harmoniously combined. This blending of different factors shows itself in the appointment of teachers. In the two hundred and ninety-six classes for the younger boys, for instance, we find seventy-seven general and thirty-seven technical teachers who devote to the work all their time and two hundred and twenty-one elementary-school teachers and one hundred and eleven technical and professional teachers who give instruction in their specialties as a side function, and one hundred and sixty teachers of religion. The essential point for an American spectator is, however, that the instruction for those thousands of young people in the midst of their practical life is given in the best hours of the day, either in the morning or in the afternoon, and that the employers are obliged to give them the opportunity to attend from six to ten hours a week for four years. Obligatory instruction in the evening when the young people come fatigued from their daily labor is excluded by the scheme. There is perhaps at present in the system of German school work no feature which so much deserves the attention of the American reformer as this whole plan of continuation schools as developed in the city of Munich and as more or less similarly organized in a large number of German cities.

THE PROGRESS OF SCIENCE

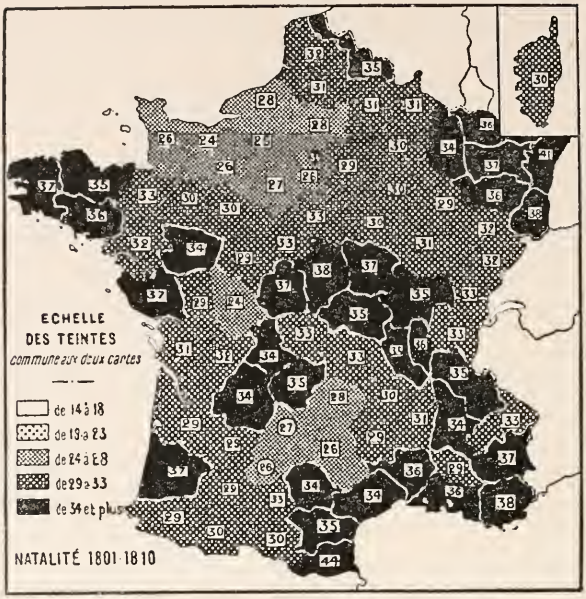
THE STATIONARY POPULATION OF FRANCE

Germany and France have happily settled their differences in regard to Morocco; but the German chancellor is charged in his own country with yielding not to France, but to Great Britain. France, which a hundred years ago lorded it over the Germanic nations and forty years ago believed that its military forces were superior to those of the German empire, has now almost lost its place among the great nations of Europe. Paris is nearly the same city it was forty years ago; Berlin is a new city. This alteration in the position of France is due to its stationary population. At the end of the last century the population of France formed one quarter of that of the civilized powers of the world, while at present it has fallen to seven per cent.

This state of affairs is causing much anxiety in France; it is discussed in detail in a recent book by Dr. Jacques Bertillon, chief of statistics for the city of Paris. The data which he reviews in detail deserve consideration not so much because, as he claims, they are peculiar to France, but rather because France has been first to exhibit a state of affairs likely soon to be evident everywhere. The charts here reproduced show the birth rates and death rates of four nations during the second half of the nineteenth century and the birth rates in the different regions of France for the first and last decades of the nineteenth century. It is almost incredible that there should be departments in which there are three deaths for every two births. In Lot the population has in the course of twenty years decreased from 271,514 to 216,611.



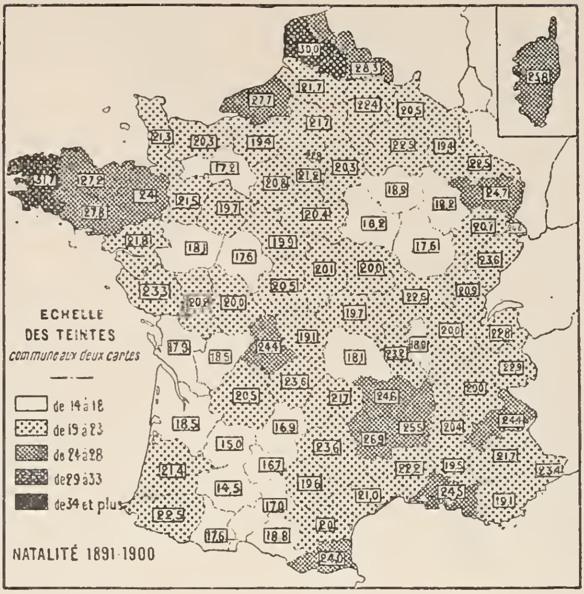
Birth Rates and Death Rates.



BIRTH RATES IN THE FRENCH DEPARTMENTS

Every nation except France is increasing in population; but the birth rate is decreasing everywhere. Statistics can be misapplied to almost any purpose. Thus since 1876 the birth rate for France has decreased from 25 to 21 per thousand, whereas for England it has decreased from 36 to 27, and it might be alleged that, should the same decrease continue, the birth rate after an equal period would be about the same for France and England, and about a hundred years thereafter would be 5 in France and less than nothing in England. This is obviously absurd, but it is by no means unlikely that the birth rate will fall below the death rate in all civilized nations and later in other nations as they are brought within the circle of European civilization.

The increase in population during recent years has been due to the decreased death rate. This has resulted directly from the applications of science to medicine and hygiene and indirectly from the improved conditions of living which science has made possible. In all civilized countries the birth rate is now smaller than the death rate was formerly. But the death rate can not decrease indefinitely; it has indeed possibly reached in Great Britain a lower level than can be maintained. A death rate of 16 per thousand in a stationary population means that the average length of life is over 60 years and as one fourth of those who die are under five years of age the average age at death of those surviving infancy would be about 80 years. Odd as it may appear at first sight the decreased death rate of a country such as Great Britain is largely due to a decreasing birth rate combined with an increasing population. Such conditions give a population in which there are fewer children under five and fewer old people over sixty, in which groups the death rate is about 60 per thousand, whereas between the ages of 5 and 35 it is below 5. In France there are fewer children than have ever existed in any population, which reduces the death rate; but there are more old people—twice as many as in Great Britain—which increases it. The proportion of old people will further increase in France,



At the Beginning and End of the Nineteenth Century.

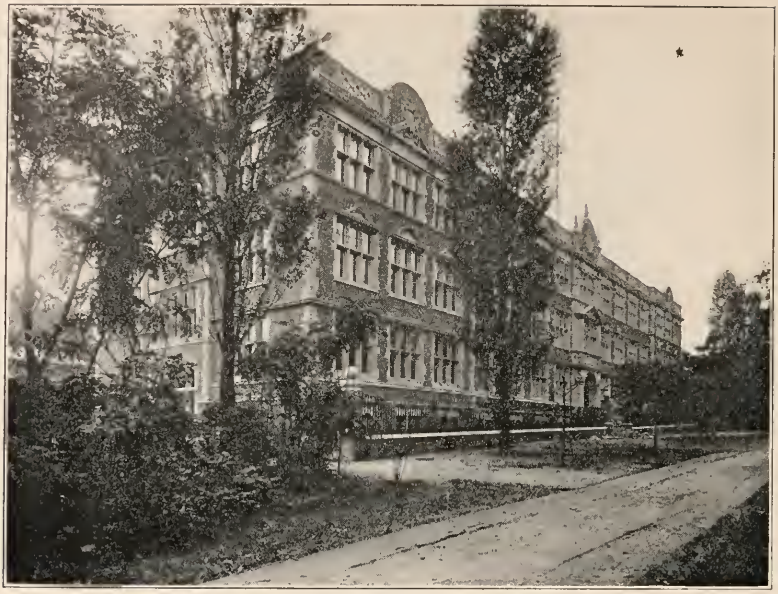
and will be tripled in Great Britain. It should also be remembered that the death rate of those over 45 has increased continually, owing mainly to the keeping alive of weakly people at earlier ages.

It seems unlikely that the death rate will ever be considerably smaller than it now is in England, whereas the conditions which have lowered the birth rate seem destined not only to continue but to increase. The physiological limitations will doubtless increase as children grow up who could not be born naturally or be nursed naturally or live through the harsher conditions that formerly obtained. The economic and social causes—the increase and wider diffusion of wealth, prudence and knowledge—will almost surely become more potent.

Dr. Bertillon discusses in detail the causes of the depopulation of France and the measures which he recommends to arrest it. The latter are indeed feeble in comparison with the former, and he puts on his title page the pessimistic motto "Il n'est pas besoin d'espérer pour entreprendre ni de réussir pour persévérer." Apart from a moral regeneration leading people to want to do what they can rather than to get what they can, the remedy is in the direction recommended in the book, but requires far more radical measures. Children are no longer a financial asset to their parents, but they are this to the state and to the world; the state must ultimately pay for their birth and rearing.

THE ZOOLOGICAL LABORATORY OF THE UNIVERSITY OF PENNSYLVANIA

Four of the leading eastern universities—Pennsylvania, Johns Hopkins, Princeton and Yale—have provided new laboratories for their departments of zoology. At the Johns Hopkins the laboratory is part of buildings planned for the whole university on its removal to a new site. At Princeton great buildings have been erected for the natural sciences and for physics, and similar buildings are in course of erection for Yale. The new building at the



Zoological Laboratory of the University of Pennsylvania.

University of Pennsylvania, shown in the accompanying illustration, is the largest and best equipped building in this country, if not in the world, devoted wholly to zoology.

The architecture is of early English Renaissance, with walls of red brick in a variety of shades trimmed with Indiana limestone. The front façade, facing the north, is 216 feet in length; the south wing connects with the vivarium erected in 1900. The form of the building and the large windows give ample light to all rooms. Excellent as are the architectural effects they have in all cases been adjusted to the needs of the scientific work. The unit system of construction has been followed, so that rooms are of standard size and partitions can be readily added or removed.

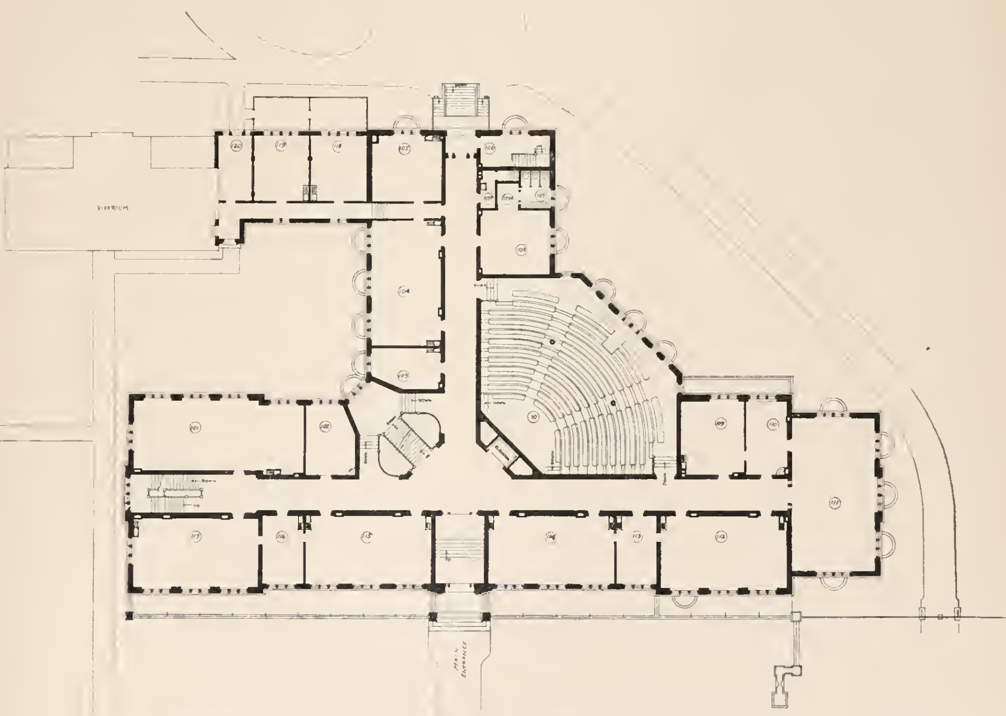
The large lecture room seats 327 students and the smaller sixty, while the laboratories may also be used for lectures. Ample space is provided for the library and for a synoptical museum, but duplication of the exhibition museums of the Academy of Natural Sciences was wisely avoided. The elementary work is confined to the first floor, with four laboratories for general zoology, leaving the two upper floors for advanced work and research. The basement contains rooms for breeding, constant temperature, photography and other purposes, the heat and light being supplied from a central station.

The United States would make unparalleled contributions to the advancement of science if these follow in proportion to the material equipment of its universities and government bureaus. But men are more important than their tools. It happens that of the great universities of the Atlantic seaboard the two—Harvard and Columbia—which lead all others in their zoological work are the only ones not having new laboratories. They will doubtless soon have them, but how much their investigations will be aided by the building, equipment and care of new laboratories is an open question. At Pennsylvania there is only one full professor of zoology. The interest on the cost of the building and grounds and the charge for care and depreciation is much larger than the salaries paid to the teachers and investigators who occupy the building. The writer has good reason to remember well the old Biological Hall of the University of Pennsylvania. It cost perhaps $30,000; it was likely not only to burn down but to tumble down. Yet in that building some twenty years ago worked Leidy, Cope and Ryder, with two other professors in the zoological sciences, two professors of botany and a professor of psychology, all actively engaged in research work. Our universities doubtless need big buildings, but the need of great men is far more urgent.

SCIENTIFIC ITEMS

We record with regret the deaths of the Rev. Henry C. McCook, of Philadelphia, known for his publications on popular entomology; of M. Louis-Joseph Troost, the eminent French chemist; of Professor August Michel-Levy, the distinguished French geologist; of M. Alfred Binet, director of the psychological laboratory of the University of Paris; of Dr. Wilhelm Dilthey, formerly professor of philosophy in the University of Berlin; of Dr. J. Hughlings-Jackson, F.R.S., eminent English neurologist, and of Professor Florentino Ameghino, the well-known paleontologist and director of the Museo Nacional in Buenos Aires.

Mr. Andrew Carnegie has given $25,000,000 to the Carnegie Corporation of New York, incorporated by the legislatiure last June. The objects of the corporation are ''receiving and maintaining a fund or funds and applying the income thereof to promote the advancement and diffusion of knowledge and understanding among the people of the United States, by



Plan of the First Floor of the Zoological Laboratory of the University of Pennsylvania.

aiding technical schools, institutions of higher learning, libraries, scientific research, hero funds, useful publications, and by such other means as shall from time to time be found appropriate therefor.''

By the will of Mr. Joseph Pulitzer the million dollars which he had set aside for a School of Journalism at Columbia University is released, and the promise of an additional million on condition that the school be successfully conducted for three years is confirmed. $250,000 is bequeathed to Columbia University to continue the special scholarships for students of the New York public schools. $500,000 is bequeathed to the Metropolitan Museum of Art and an equal sum to the Philharmonic Society of New York. The income to be paid to two of his sons is limited until they have reached the age of thirty, and the balance is to be divided between Columbia University, the Metropolitan Museum of Art and the Philharmonic Society. This amount may apparently exceed $500,000 annually.

The will of Miss Emma Carola Woerishoffer leaves $750,000 to the trustees of Bryn Mawr College, of which she was a recent graduate.

The estate of John S. Kennedy is even larger than has been previously announced. The share of Columbia University is $2,429,943. The New York Public Library receives $2,779,790; the Metropolitan Museum of Art, $2,929,943; the Presbyterian Hospital, $1,514,086; New York University and the Presbyterian Board of Aid for Colleges, each $976,647; Robert College, Constantinople, $1,847,295. The specific bequests, not dependent on the size of the size of the estate, include $100,000 each to Yale, Amherst, Dartmouth, Bowdoin, Hamilton and Glasgow.

INDEX

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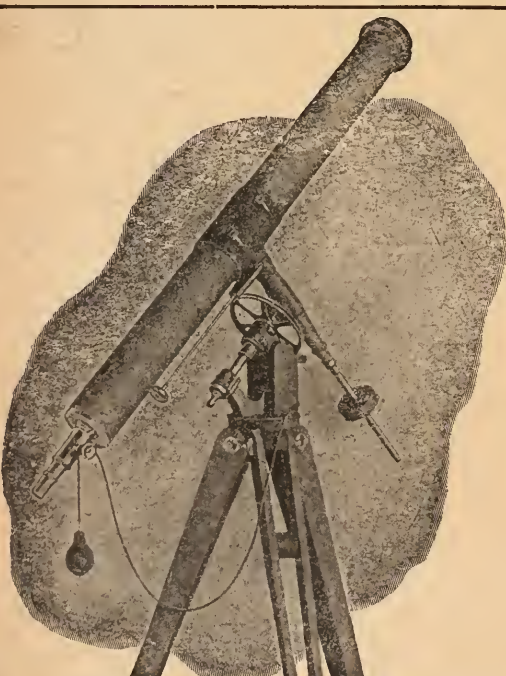

Illustration shows 5-in. with pneumatic clock.

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