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THE SMALLEST OF THE CENTURY PLANTS[1]

By Professor WILLIAM TRELEASE

MISSOURI BOTANICAL GARDEN

SELECTION of these particular plants from the very large number that have occupied my attention for the last ten years is based on a recognition of the fact that it is extremes—the largest and smallest,

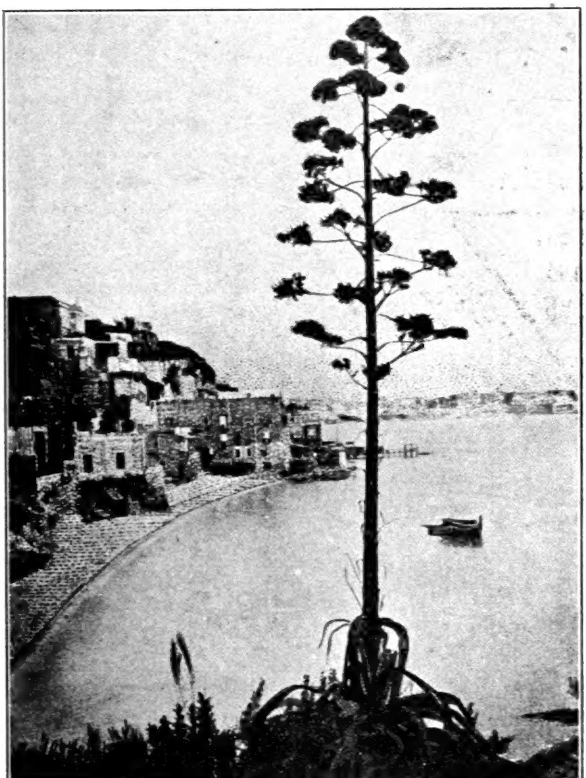

Fig. 1. About the Mediterranean.

[1] A lecture before the Academy of Science of St. Louis, delivered October 17, 1910.

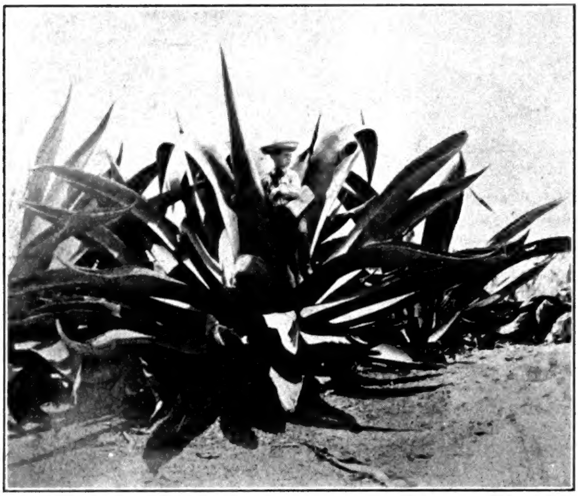

FIG. 2. GROWN FOR PULQUE.

the best and the worst—rather than ordinary or average things which attract human interest. The present very short communicaion may be called a vest-pocket account of the vest-pocket edition of the century plant. The use of this name, however, is not quite accurate, for the century plant properly is that large *Agave,* standing as the type of its genus, which was introduced into Europe not so very long after the discovery of the new world by Columbus, which has now become thoroughly naturalized about the Mediterranean, and which in northern

FIG. 3. THICK AS A MAN'S BODY.

countries, even when protected against the winter, literally takes the larger part of a century for its development. In the popular mind the idea of a century plant also includes the enormous species grown for pulque on the elevated plains to the south of the City of Mexico, and even larger plants of the same type, each of them reaching the weight of a ton or more, and sometimes producing a flower stalk nearly as thick as a man's body. In this sense, then, the name century plant becomes nearly equivalent to the Haitian name maguey, as now applied in Mexico, where the Spaniards introduced it in place of the Aztec name for these plants—metl. My use of the word, then, is rather as an equivalent of the botanist's generic name, *Agave,* than of this particular designation of a part of its species.

Fig. 4. Giants and Pygmies.

A comparative notion of the size of these giants of the genus and its pygmies, with which I am here concerned, is afforded by a photograph of the latter, taken by the side of two of the fruiting branches of a mammoth West Indian species which I have hanging to a chimney breast in my study. The larger of these dwarfs is no larger than one's fist, and the smaller scarcely equals the seed-vessel of a great maguey.

Fig. 5. Scarcely equals a Seed Vessel.

The larger of these species was first discovered by the international survey of the boundary between Arizona and Sonora, more than half a century ago, and although it is abundant on the ragged mountains of the boundary region, it has been collected very few times so far as yet known, since then: ten years ago near the one hundred and twenty-ninth boundary monument in the Pajarito Mountains by myself when I was looking up typical material of some of the species first made known through the International Boundary Survey; last year when

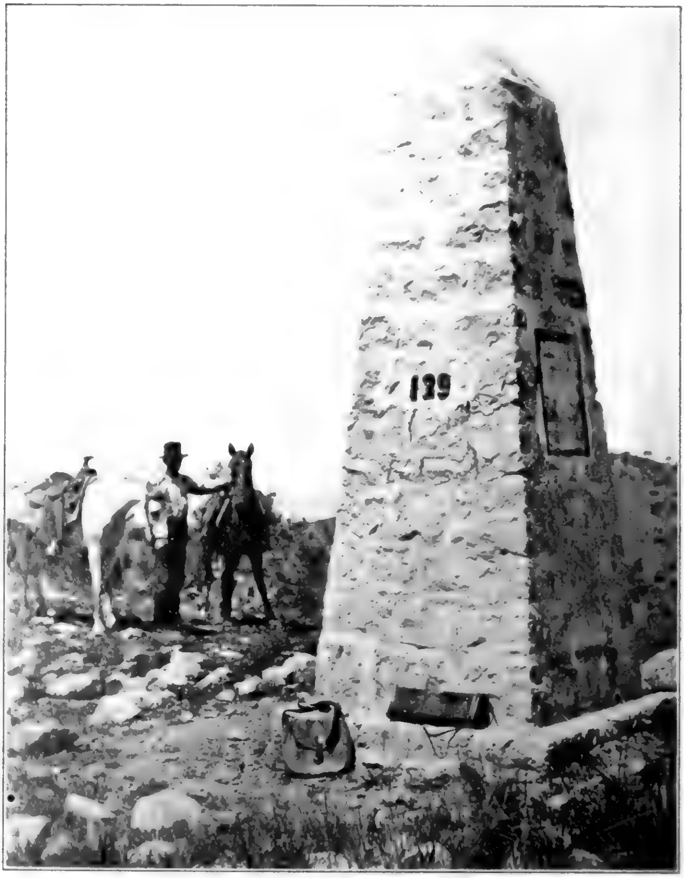

Fig. 6. In the Pajarito Mountains.

Mr. J. C. Blumer collected it in the same region; and this season when Mr. James H. Ferriss found it in the Guija Mountains. The little plant here illustrated is the one sent in by Mr. Blumer, which in transit had begun to develop a flower stem and which, flowering in May of last year and fruiting in the following summer, has given the first opportunity for a botanist to observe these phenomena and to see in perfection its diminutive flowers which, scarcely three quarters of an inch long, led its describer, Dr. Torrey, to name it *Agave parviflora.*

Like those of many agaves and yuccas and some other genera the solid stem and thick leaf bases of this plant contain a saponifying substance which has won for it, as for these various plants, the name amole, or soap-weed. Its thick, rounded leaves, like those of a comparatively few other species in the genus are beautifully marked by irregular stripes of pure white, due to bits of cuticle torn from other leaves as the central bud or cogollo opened. When Dr. Engelmann presented his classical notes on *Agave* to the academy thirty-five years ago, he stated that the occurrence on the margins of these leaves of detaching threads above and little prickles below was, so far as known, unique in the genus, and except for a very few close relatives of this plant the statement still holds true.

FIG. 7. CANDELABRUM-LIKE PANICLES.

The main kinds of *Agave* fall into two recognized classes: one, illustrated by the true century plant and the pulque magueys, bears flowers in candelabrum-like panicles; the other, like the lechuguilla, has its flowers disposed mostly in pairs along a wand-like spike. An effort has been made to separate these latter from *Agave* under the generic name *Littœa,* but this has not met with general acceptance and in fact there are puzzlingly intermediate species, as, for instance, the *Littœa*

FIG. 8. A WAND-LIKE SPIKE.

characteristic of the Grand Cañon, and a garden *Littæa* which many years ago I named in commemoration of the accurate student of this group of plants, Engelmann.

Agave parviflora is clearly a *Littæa,* with its flowers rather loosely disposed along the upper part of an inflorescence wand scarcely thicker than a goose-quill, but its flowers by no means grow in pairs, though each short main stalk forks at the beginning. On the contrary, clusters of six or eight flowers—of which all but two or four commonly fail to develop—are borne by its forked primary branches, a study of which is capable of throwing much light on the reduced rather than primitive typical twin flowers of the littæas.

As with all of the agaves that have been studied so far, this species matures the stamens and pistils of a given flower at different times. The flowers, which open early in the morning, quickly protrude their stamens and shed their pollen immediately, but the style is then no

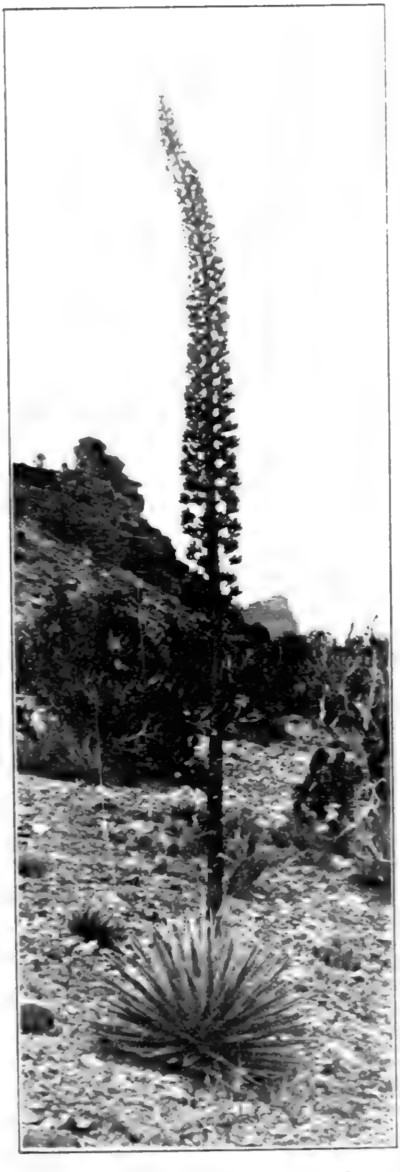

FIG. 9. CHARACTERISTIC OF THE GRAND CAÑON.

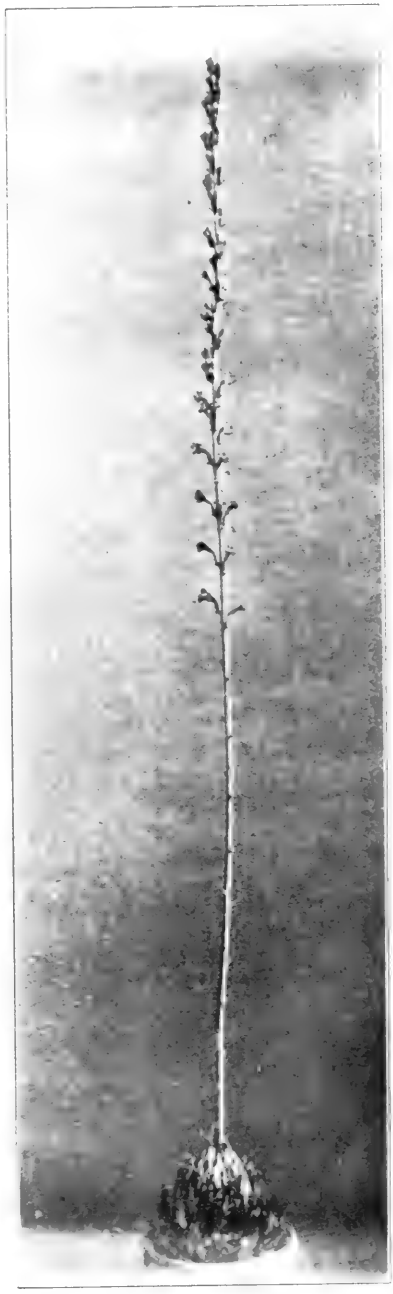

FIG. 10. *Agave parviflora.*

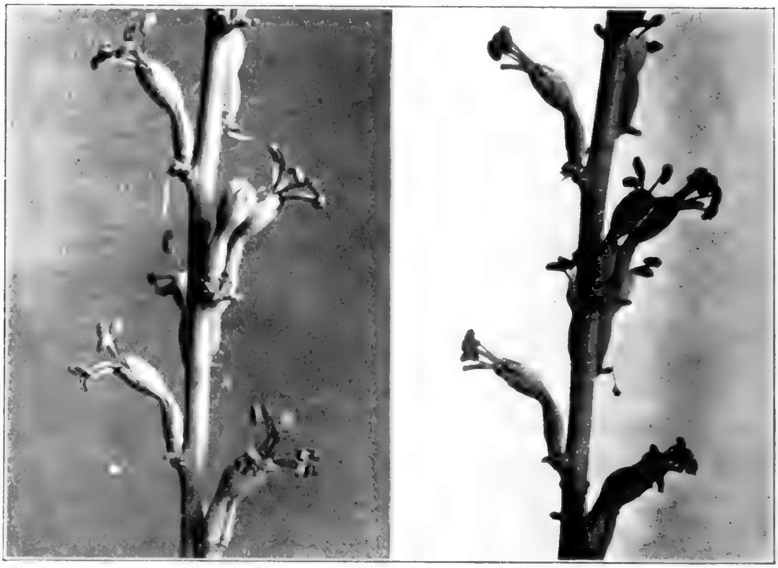

FIG. 11. EARLY IN THE MORNING. FIG. 12. THE NEXT MORNING.

longer than the perianth and its stigma is not receptive for pollen. By the next morning, however, the style has reached the stamen in length, though it is still unreceptive. After two days, the stamens have shriveled and drawn out of the way and the stigmatic lines have become fleecy and moist, indicating receptivity. Though scentless, and greenish white, rather than brightly colored, the flowers secrete an abundance of nectar which with the proterandry points to cross pollination by the aid of insects.

When Arthur Schott collected the type specimens of *Agave parviflora* it was in fruit, though the upper part of some of the specimens still retained a few unopened buds, and a few sterile, dried-up flowers were included in the collection. My own observation of the plant in the field was also made during its fruiting season and I am not aware that its fresh flowers have ever been seen except on this specimen. The main structural characters of the flowers were accurately made out by Engelmann and are preserved in his perfectly prepared dissections, but the contribution which this little specimen has made to a correct understanding of their shape and proportions is clearly shown by a comparison of these type flowers with its own.

Almost if not quite as small as *Agave parviflora* are two other species in many respects closely similar to it: a little plant found in northern Mexico on the Lumholtz expedition, which Mr. Watson named, after its discoverer, *Agave Hartmani,* and an unnamed plant of similar habit but with a short perianth tube equalled in length by the perianth lobes, which Professor Toumey found eighteen years ago in the Pinal Mountains of Arizona. In the course of my study of this group of agaves with thread-margined leaves I have also encountered a garden plant of about twice the dimensions of *A. parviflora* and with differently shaped leaves, which has been grown under the name of *parviflora* but which is not unlikely to prove more closely related to the thread-bearing amoles of central Mexico. The prickly margin and its replacement by detaching threads which characterize *parviflora* are particularly well shown on the juvenile foliage of offsets from this plant.

The other and still smaller dwarf first came into the market under the trade name *Agave pumila*—given because of its minute size—about thirty-five years ago, the earliest mention of it that I find being in a catalogue published in 1877. No record is available as to the source of the plants then or now in commerce, though I have been told that a collector of such plants has seen it in the Andes of Colombia. Like many other agaves, this produces offsets freely and is now rather extensively cultivated. It was named in 1888 by Mr. Baker, who stated that his plant—about as large as the one here shown—had not increased appreciably in size for the eight years during which it had been cultivated at Kew. Though I have no doubt that it grows to something more than this walnut-size, I shall be surprised if it ever reaches the proportions of *parviflora*. It is known in botanical literature only from the original description. Its very thick leaves have short, sharp end-spines, decurrent on the margin in a dried line of the same texture as the little marginal prickles. From the fact that this margin was not continuous, Mr. Baker was led to range *Agave pumila* in his submar-

FIG. 13. JUVENILE FOLIAGE.

FIG. 14. LINED WITH DARK GREEN.

ginate series, which brings this, the least of all agaves, close beside the greatest of its congeners, the gigantic pulque magueys. It would be surprising if, when its flowering is made known, *pumila* were found to develop a diminutive candelabrum inflorescence; in fact, this is not to be expected. A character shown by this specimen and, so far as I know, never before noted publicly, is that the backs of its leaves are finely lined with dark green on a lighter background. Though generalizations are unsafe, I may say that in the course of an exhaustive study of all of the agaves that it has come my way to see I have thus far seen such lining only on littæas of the horny-margined section, like the lechuguilla—the marking being due, in fact, to the development of what may be called an emergency water tissue on the lower side of the leaves, the darker green stripes marking points at which the full chlorophyll-bearing tissue comes out to the epidermis and the water tissues developing more or less chlorophyll according to differing conditions of drought and exposure to light. There is every reason to believe, therefore, that when it flowers *Agave pumila* will produce a littæa spike and flowers similar to, if not so large as, those of *A. lecheguilla*.

FIG. 15. THE LECHUGUILLA.

No agaves are known south of the isthmus of Panama except one of the West Indian panicled series which has developed in the Venezuelan coast region, and a little-known plant of the Andes, near Lima, which is evidently a littæa, though of a mezcal series, quite unrelated to the horny margined group. It need, therefore, be little more surprising if *Agave pumila* of the latter group is found to be really at home in the Andes, than that another littæa type should be found in the same exile, though relatives of the latter are characteristic of southern Mexico while known marginate species are more northern.

EUTHENICS AND EUGENICS

By Dr. C. B. DAVENPORT
COLD SPRING HARBOR, L. I.

OF late years the reading, thinking public has been awakened to a realization that sickness, poverty and crime are great and perhaps growing evils. It does not seem right that there should always be about 3 per cent. of our population on the sick list, that our alms houses should support over 80,000 paupers, not to mention the hundreds of thousands that receive outdoor relief or are barely able to earn a living; and that there should be 80,000 persons in prison. It ought not to be that the nation should have to support half a million insane, feeble-minded, deaf and blind and that a hundred million dollars should be spent annually by institutions in this country for the care of the sick, degenerate, defective and delinquent. It is a hopeful sign of the times that people are asking: "What can we do about it? What is the cause and what the remedy for this state of things?"

The answers to this inquiry take two general trends. One set of reformers urges that the socially unfit are the product of bad conditions and that they will disappear with the establishment of some modern Utopia. The other set of reformers urges that the trouble lies deeper—in the blood—and is the outcome of bad breeding; the trouble will disappear if marriage matings are made more wisely.

The point of view of the first set of reformers may be made clear by some quotations from their works. Thus Henry George, Jr., in his book, "The Menace of Privilege," after stating that there is an increase of insanity, suicides and crime asks: "From what does all this proceed?" and he replied: "Poverty. It means privation . . . insanity, suicide, crime." Mrs. Ellen H. Richards has stated the position of these reformers so well that I am constrained to make numerous quotations from her valuable book entitled "Euthenics"—a name that may well be applied to the point of view that is contrasted with eugenics. She says: "Of all our dangers that of uncleanliness leads" (p. 19). "The necessity of judicious, wholesome food is paramount" (p. 22). "Mr. Robert Hunter says: 'Perhaps more than any other condition of life it [food supply] lies at the door of the social and mental inequalities among men'" (p. 23). "A strong, well man, whose work is muscular and carried on in the open air, as is that of the farmer and of the fisherman, will have the power to assimilate almost anything" (p. 24). "Just as soon as the individual fully realizes that he himself is to blame for his suffering or his poverty in human energy, he will apply his intelligence to the bettering of his condition" (p. 26). "Why are men and women so apathetic over the prevalence of disease? Why do they not devote their energies to stamping it out? For no other reason than their disbelief in the teachings of science, coupled with a lingering superstition that, after all, it is fate, not will power, which rules the destinies of mankind" (p. 28). "There is no greater evil than the congestion of streets and buildings" (p. 48).

In apparent contrast to the euthenics view of the importance of conditions is the eugenics view of the importance of blood. Taking an extreme case, a child is born an imbecile and neither the best of nutrition, the most scrupulous cleanliness, the purest air and sunshine, nor the best of physical and mental training will make anything else out of him. Imbecility can not be cured; in most of its forms it is a necessary result of the nature of the parental mating. It is a defect due to a patent or latent defect in both of the paternal germ plasms. The imbecile is an imbecile for the same reason that a blue-eyed person is blue-eyed.

Lest you have not heard where a blue-eyed child gets its eye color, let me recount the story. Brown eyes are due to a brown pigment laid down in the iris; blue eyes are due to a lack of such pigment. When both parents are brown-eyed the children get the tendency to form iris pigment from both sides of the house, and the condition of the pigment is said to be duplex. If the children get the tendency from one parent only, they still have brown eyes, but the condition is said to be simplex. If both of the parents lack brown eye-pigment, that is proof that the power of producing it is absent from their germ cells. Now, what is absent from the germ cells can not be transmitted, consequently, two parents lacking brown in the iris (blue-eyed) will never have children with brown eyes, but only with blue eyes. If both parents have brown eyes simplex, then one in four of the children will have blue eyes. If one parent has simplex brown eyes and the other has blue eyes, one half of the children will have blue eyes. But, if in both or either one of the parents the brown iris pigmentation is duplex all of the offspring will have brown eyes.[1]

TABLE OF MATINGS AND OFFSPRING—EYE COLOR

One Parent	Other Parent	Offspring	
PP	PP	PP, PP.	All with pigmented iris (brown-eyed).
PP	Pp	PP, Pp.	All pigmented, but half simplex.
PP	pp	Pp, Pp.	All pigmented and all simplex.
Pp	Pp	PP, Pp, pP, pp.	¼ duplex pigmented; ½ simplex; ¼ unpigmented (blue-eyed).
Pp	pp	Pp, pp.	½ simplex; ½ unpigmented (blue-eyed).
pp	pp	pp, pp.	All unpigmented (blue-eyed).

[1] These different cases of inheritance fall into six groups as in the following table, in which PP stands for duplex pigmentation, Pp for simplex pigmentation and pp for lack of pigmentation.

Now, it will be observed, says the extreme eugenist, that these rules hold no matter whether the children develop in the city or in the country, in moist climate or dry, under conditions of good nutrition or of poor. And what is true of eye color he would maintain is true for skin and hair color, for stature, for abnormal fingers and toes, for diseases of various sorts. Even criminals, like poets and artists, are born and not made. It is not poor conditions that create insanity, but poor blood; not the germ of tuberculosis, but non-resistant protoplasm that causes death from consumption.

Thus the two schools of euthenics and eugenics stand opposed, each viewing the other unkindly. Against eugenics it is urged that it is a fatalistic doctrine and deprives life of the stimulus toward effort. Against euthentics the other side urges that it demands an endless amount of money to patch up conditions in the vain effort to get greater efficiency. Which of the two doctrines is true?

The thoughtful mind must concede that, as is so often the case where doctrines are opposed, each view is partial, incomplete and really false. The truth does not exactly lie between the doctrines; it comprehends them both. What a child becomes is always the resultant of two sets of forces acting from the moment the fertilized egg begins its development—one is the set of internal tendencies and the other is the set of external influences. What the result of an external influence—a particular environmental condition—shall be depends only in part upon the nature of the influence; it depends also upon the internal nature of the reacting protoplasm.

I have two dogs, a fox terrier, and a bird dog. They come upon a wounded bird. The terrier sniffs at it and passes it by, but the retriever picks it up and carries it for a time in its mouth. Is it simply the wounded bird that determines the retriever's action? Clearly no, since the bird did not cause the same response in the terrier. Is it alone the nature of the retriever that determined the carrying; no, since he would not similarly carry a stone. The result is due to the *bird* acting on the peculiar *constitution* of the retriever. So, in general, any human behavior is the resultant of the specific stimulus and the specific nature of the reacting protoplasm. Development is a form of behavior and how a child shall develop physically, mentally and morally is determined not by conditions alone, not by blood alone, but by conditions *and* blood; by the nature of the environment and the nature of the protoplasm.

This principle may be applied generally and it holds true even in diseases. It is an incomplete statement to say that the tubercle bacillus is the cause of tuberculosis, or alcohol the cause of delirium tremens. Experience proves it, for not all drunkards have delirium and not all that harbor the tubercle bacillus die of consumption—else we must all die of that disease. No, the causes of death as given in the health reports or census bulletins are not the real causes. All of these results are due to an inciting condition acting on a susceptible protoplasm. The real cause of death of any person is his inability to cope with the disease germ or other untoward condition.

The fact that of all occupations of females that of servant shows the highest death rate from consumption does not imply that this occupation is extra-hazardous to the lungs or to body-resistance rather than that servants are largely Irish (who as a nation lack resistance to tuberculosis) or that they are below the average in mental and physical development, including disease resistance.

What is true of consumption is true of various diseases that are commonly thought not to be due to germs, but to conditions of life. Insanity is one of these. Mr. A. goes insane; we explain that it is because of business losses or overwork. But there are a lot of us who have severe losses or who work hard and show no signs of nervous breakdown. It would be more accurate to say A. went insane because his nervous machine was not strong enough to stand the work put upon it. Insanity (except perhaps paresis and the so-called "alcoholic psychoses") rarely occurs except where the protoplasm is defective. Also epilepsy, which is so often ascribed to external conditions, is, like imbecility, determined chiefly by the conditions of the germ plasm; and the trivial circumstance that first reveals the defect is as little the true cause of the defect as the touching of the button that opens an exposition is the motive power of the vast engines.

The variations of density in the geographic distribution of a disease, upon which climatologists lay so much stress, does not always warrant the popular interpretation of the facts. A heavy incidence of disease in any county does not always mean unfavorable environment. I have plotted the distribution of imbeciles received by an institution in a small state. The ratio of incidence of this condition to the entire population is high in some counties (chiefly *rural*) and low in others, due to the presence or absence of foci of the defect. Similarly the varying rate of deaf-mutism is determined by the density of defective germ plasm. So, also, despite its fine climate, the rising generation in California is characterized by diseases of the mucous membranes, because a generation ago much weak protoplasm was attracted to this state as a sanatorium. No, blood is as important a factor in determining the occurrence of disease as climate.

Crime, which the euthenist finds so related to conditions, proves to be, like disease, a resultant of conditions and blood. Only so can we explain the pedigree trees of criminal families like the Jukes and the Zeros. Tactful, firm, sympathetic, just treatment can do much to reform juvenile delinquents, but if the moral sense and balance are absent the treatment will avail little or nothing. Upon the children of the "Zero" family the priest-school was without effect. The time and pains required for reformation will, in any case, depend on innate qualities of the delinquent.

In respect to talent the importance of both blood and training is generally recognized. Many "lightning calculators" and mathematical prodigies are born and are not at all the product of training, yet training improves the gift for mathematical abstractions. In the realm of vocal and instrumental music the same is true. Even the *prima donna* must be trained. Though the Bach family contained musicians for eight generations, and twenty-nine eminent ones assembled at one family gathering, still training no doubt added to the value of their performances, at the same time that their inborn capacity rendered them apt scholars.

The objection has been raised, as we have seen, to recognizing that heredity has any considerable importance in determining unfavorable results, on the ground that it is a pessimistic and fatalistic doctrine. Euthenics, on the other hand, offers opportunity to do something to improve a person's condition. Apart from the fact that the truth must be faced whether pleasant or not, the contention can not be too strongly urged that improvement of conditions is only palliative, while improvement of blood is essential to permanent progress. Our only hope, indeed, for the real betterment of the human race is in better matings. If any one doubts this let him ask the agriculturalist. Let him ask the Florida orange grower, who no longer fears the frost, if heredity is a "terrible" fact; let him ask the "dry farmer" of Montana, who cultivates his special varieties that require little rain, if heredity gives him the blues; let him ask the breeder of improved Holstein cattle whether he would, if he could, annihilate the fact of transmission of qualities; they would laugh in your face; they would assure you that heredity is their main reliance and their most precious tool. So to the eugenist heredity stands as the one great hope of the human race; its savior from imbecility, poverty, disease, immorality. But, to be effective, the available salvation must be accepted. By some means or other the principles of eugenics already known, and those which studies now being undertaken will surely reveal, must be applied in marriage selection. To-day, marriage is controlled imperfectly, crudely, by social ideals. Incest, cousin marriages, the marriage of defectives and tuberculous persons, are, in wide circles, taboo. This fact affords the basis for the hope that, when the method of securing strong offspring, even from partially defective stock—and where is the strain without any defect?—is widely known, the teachings of science in respect even to marriage matings will be widely regarded and that in the generations to come the teachings and practise of euthenics will yield the greater result because of the previous practise of the principles of eugenics.

THE METEOROLOGY OF THE FUTURE[1]

By Professor CLEVELAND ABBE

U. S. WEATHER BUREAU

AFTER some introductory remarks by Dr. Finley, president of the College of the City of New York, Professor Abbe said:

I think myself specially honored by these kindly words from the president of the College of the City of New York. You all know how thoroughly that noble institution has, during the past sixty years, entrenched itself in the hearts of our citizens, and you know what Dr. Finley is doing to carry its work forward. To it many of us owe those youthful inspirations that have determined our careers in maturer life. It is always a delight to me to recall the years 1851–1857 when at that college I studied the foundations of modern physical science; mathematics under Docharty, descriptive geometry under Koerner, mechanics under Nichols, physics and chemistry under Gibbs. Not to speak of those other revered instructors, Owen in Latin and Greek, Anthon in history, Duggan in architecture, Roemer in French. Each one of these is still to me a living inspiration. Such men do not die so long as their words and lives continue vividly before us. It was worth living in those days to have listened to the brilliant diction and witnessed the successful experiments of Robert Ogden Doremus in his lectures on the Nebular Hypothesis. These admirable educators dealt with questions that I have gradually come to see are intimately associated with our atmospheric problems, though they themselves probably did not think of such connection at that time. It may be said that every course of study then pursued at that college has proved useful in the modern development of meteorology. Of course this is equally true of the studies now pursued at Columbia University. May both that college and this university in the future send forth many meteorologists and others to benefit our city, our nation and our science.

My task to-night is to be as difficult as the problem proposed of old by Pharoah to Joseph. I am to tell you a dream of the future of science and also the interpretation thereof.

In the preceding nine lectures, my colleagues have given you some idea of the present state of our knowledge of the atmosphere. Possibly you may have already suspected that we know very little about the air in which we live. You must not think less of the honest scholar when

[1] A public lecture, illustrated with experiments, at Columbia University, March 16, 1909.

he assures you that what we really *know* beyond all peradventure is as nothing compared to the unknown ocean of truth still to be explored. I trust that you will sympathize with my enthusiasm over the study of the atmosphere. Does not the wonderful glory of a sunset sky stimulate one to study its causes and to discover what its clouds and colors have to do with the weather of to-morrow? Who can watch the approach or recession of a thunder-storm and not be impressed with the dreadful majesty of its appearance? We may dream of the immensity of space as we contemplate the star-lit sky at night, for the stars are far, far away and men are always dreaming of them—but we can not merely *dream* of the clouds, the weather and the storms; the atmosphere is too near at hand for mere dreams; it forces us to action; it is close to us; we are in it and of it. It rouses us to both study and do; we must know its moods and also its motive forces; we must conquer it in our struggle for existence. Now that our aeronauts Orville and Wilbur Wright have learned to fly, we must learn to utilize the air just as the mariners have learned to utilize the winds and avoid the storms.

In the days of Columbus (1437–1514), Drake (1540–1596), Dampier (1652–1715) and Halley (1656–1742) the mariner long ago knew of the trade winds and the seasonal monsoons and the prevailing westerlies, and took advantage of them. It took two more centuries to acquire a knowledge of whirlwinds as they advance over the globe; and only the present living generation of men has seen the growth of national and local weather bureaus in every part of the civilized globe established to forewarn mariners of storms, or landsmen of rain and wind, frosts and blizzards. We are not yet able to speak of such weather forecasts as anything more than probabilities or indications, they have not yet become certainties, but surely you are all convinced that already, even in the present imperfect state of our knowledge, the meteorologist is worthy to be recognized as a benefactor of mankind.

Has any community in this country or in the whole world profited by the steady daily watchfulness of such a weather bureau more than this very city of New York? Thousands of your law cases are decided annually on the testimony of official weather records. Your business men are forewarned of every storm. Whenever current weather conditions threaten misfortune to any special branch of industry you make a hundred inquiries by telephone, telegraph or personally, asking for details as to what is going on overhead. Your morning papers and your evening papers are consulted by every one for the weather forecasts; your business matters are arranged in accordance with the conviction that one can not afford to neglect this little item of information, any more than he can afford to neglect ordinary insurance, even though he knows that there is a chance for an occasional mistake. The daily weather map is distributed as widely as possible for the benefit of all and is a splendid educator. This map gives us the facts, even though the best of us often fail to perceive what they mean and what they foretell.

And right here I must remind you that this system of daily telegrams, with its maps and forecasts owes its origin and subsequent perfection almost entirely to the citizens of the city and the state of New York. New York City has always been the home of meteorologists, just as our bay with its sailing vessels and steamships has always been filled with the bravest of sailors and navigators. Others besides Hudson and Fulton, Stevens and Ericsson, Cyrus Field and Wm. H. Webb have helped to make the fame of New York and the Hudson.

Here lived W. C. Redfield, whose busy life as a merchant did not prevent him from collecting the logs of ships and studying all the characteristics of storms at sea. For forty years he devoted his leisure hours to this work, publishing one research after another from New York City, until the whole world understood that hurricanes, cyclones and typhoons are whirlwinds, revolving and progressing as a whole, moving slowly along paths that carry them from equatorial toward polar regions; that our own hurricanes move westward and northward over the West Indies into our south Atlantic and gulf states and thence north and east along our coasts to northern Europe.

Here lived Elias Loomis, teaching meteorology and astronomy for many years as a professor at the New York University, and studying the storms of the land.

Here lectured James P. Espy, a native of Pennsylvania, who, with inimitable eloquence and enthusiasm defended his great discoveries that a cloud must contain the heat that was originally consumed in the evaporation of the water; that the moist air by rising had cooled by expansion down to its dew point; that the condensation into cloud caused latent heat to be set free.

Here, and in the northern part of our state, we had B. F. Hough at Lowville, who gave us our best studies of the New York climate and our first stimulating reports on the importance of forestry.

Our dear New York, the youthful city of a century ago, was the home of Professor Samuel F. B. Morse, artist and inventor, whose enthusiasm triumphed over the difficulties in the way of perfecting the electro-magnetic telegraph, and made it possible for our great national weather bureau to carry on its work expeditiously and economically.

At Albany Professor Joseph Henry, the father of the electro-magnetic telegraph, maintained the importance of the study of the atmosphere. In 1847, when he was called from Princeton to become the secretary and brains of the Smithsonian Institution in Washington, he immediately arranged with the telegraph companies for telegrams, displayed them on daily weather maps and demonstrated the possibility of forecasting storms and weather.

Greater New York, that is to say the Brooklyn of sixty years ago, was honored as the residence of Ebenezer Meriam, "the sage of Brooklyn Heights," a manufacturer, but also special correspondent and associate editor of the New York *City Commercial,* in whose columns, about 1850, he began to publish his weather forecasts compiled by using all the information at his disposal, especially the telegrams of weather conditions in distant places. His forecasts of "heated terms" and "cold terms" not only prepared the general public to believe that weather could be predicted, but had a special influence on one young student just entering your City College, whose scrap book of 1850 still contains the history of early events that stimulated his boyish imagination and aspiration. Meriam was but carrying out single-handed the ideas urged by Redfield and Loomis, Espy and Henry, looking to the formation of a government weather bureau. The rule that weather changes move eastwardly for several days in succession was utilized by New York business men even before Professor Joseph Henry announced from Washington the general result of the labors of James H. Coffin, of Ogdensburg, N. Y. It was Professor Coffin who during the years 1838–1840 published our first American meteorological magazine and eventually compiled a great work on the winds of the globe, demonstrating that in these latitudes (between 30 and 60 degrees north) there always is a strong west wind high above the ordinary layers of clouds, that apparently explains the eastward drift of our storms.

The complete mechanism of the atmosphere was clearly explained by William Ferrel in 1858, so that finally, in May, 1868, when our country was rapidly recovering from its terrible internal dissensions, a young astronomer from New York, a graduate of your City College, who had been revolving in his mind all these teachings of his elders, and had from boyhood been observing the clouds and winds and weather, submitted to the Chamber of Commerce of Cincinnati his project of weather forecasts for the benefit of that city. He was ably supported by the officers of the famous astronomical observatory, by the citizens of the "queen city of the west," by her newspapers and her telegraph authorities. You will agree with me that he was within bounds when he wrote from Cincinnati to his parents in New York: "I have started a work that the country will not willingly let die." This was the work that in the hands of General Albert J Myer, of Buffalo, has brought such fame to our country and city.

Although the study of science and the pursuit of research is most fascinating and elevating, yet no man should be satisfied therewith. It is right to be content from day to day, but never satisfied. The highest type of man is he who seeks to be most useful to his fellow men. It is the duty of every citizen of this republic to attain the highest usefulness that he is capable of. He may temporarily devote himself to acquiring knowledge or money; to perfecting art or inventing machinery; he may apparently devote his whole life to some mercantile pursuit, but if he be true to his own conscience, his ultimate hope must be to benefit his country and mankind. Anything else less than this dies; just as he himself must die; it dies with him. Patriotic philanthropy can alone afford a man the comfortable assurance that his life has been well spent. No one founds a hospital, a library, a museum, a park or a university, for purely selfish ends; he knows, and he takes pleasure in knowing, that the whole community will be benefited, and that future thousands will thank him for that which otherwise would have been unattainable to them. He has given to his money and his life their maximum power for good.

At this moment Columbia University surrounds us with this group of noble buildings, testifying to the wisdom of many wealthy men. The names of the best of New York are inscribed above these portals. There is room for other temples and why should not one of these be devoted to the science and the art that I represent, to the study of the atmosphere, and the utilization of that knowledge for the benefit of man? Give meteorology a home of its own among these temples of science, and its students will build a noble intellectual structure. Provide generous fellowships, stimulate able physicists to devote their lives to this study, and thus assure the development of useful meteorolgy by future generations of men.

But is there a future for meteorology? Can we to-night lift the curtain and look forward? What are the problems that now seem to be pressing for solution? The great problems of the past were vital to the progress of science and to the welfare of mankind. Some of these problems still await our careful attention, and other newer ones have become prominent. This present generation of men must provide for this future study. We understand the general nature of the work that remains to be done, but a future generation must do it. It is our first duty to provide for the education of the young men that are to carry the work a few steps further forward. Progress in knowledge is always slow. How slowly Africa has been opened up. How hard it was to find the North Pole. How long the world waited for Christopher Columbus to cross the Atlantic.

With the kind assistance of Professor Wm. Hallock and his colleagues I have prepared a few experiments to illustrate the points to which I would draw your attention. But first I must emphasize my statement that as soon as one generation of men arrives at a simple law or generalization, then another generation calls attention to the fact that there are exceptions to these laws and that obscure influences are at work preventing the operation of any one single, simple law. Thus a new series of researches opens up; we descend to the study of details and try to unravel all the complexities of natural phenomena. To enforce this point we may say that in our atmosphere every local weather phenomenon results from the interaction of the following seven forces:

1. The diurnal rotation of the earth on its axis.

2. The annual revolution of the earth in its orbit.

3. The attraction of gravitation holding the atmosphere to the earth.

4. The centrifugal force resulting from the rotation of the earth on its axis, and due to the inertia of the moving masses of air.

5. The molecular forces known as heat, light, chemism, electricity and radiant energy received by radiation from the sun with all the variations depending upon latitude, diurnal rotation and annual revolution.

6. The loss of heat by radiation from the earth and atmosphere.

7. The irregular expansions due to the irregular distribution of heat in the atmosphere which depends on the distribution of continents and oceans, and the presence of an easily condensable vapor like steam mixed with the permanent gases, nitrogen and oxygen that form the great mass of the atmosphere.

You will see from this brief and partial enumeration that we have to do with very complex combinations of phenomena, and that the results must vary with every slight variation in any one of these forces. Worse than this, we have not yet been able to observe or investigate the boundary between our atmosphere and the illimitable planetary space beyond. We know not whether gaseous particles are being added to and removed from this outer boundary. We know not whether our outer layer of atmosphere experiences any resistance from the cosmic ether as the earth rushes along in space. There are many speculations as to the origin of the earth's atmosphere; not only do these belong to geology, cosmic physics or cosmology, but they also lie at the foundation of meteorology. In the present state of our knowledge these are merely speculations; dynamic meteorology passes them by in silence and assumes that the atmosphere is now unchangeable as to its composition and mass. But who knows how soon the day will come when we shall have to recognize that a change has taken place! From this point of view I should say that in logical order the first problem for future study bears on the condition of the outer layer of our atmosphere, and in fact, my predecessors in this course of lectures, Professor R. S. Woodward, of Washington, and Professor J. H. Jeans, of Princeton, have already touched upon this question. More than that, Dr. C. C. Trowbridge, of Columbia University, has brought together many interesting facts relating to the trains left behind by meteors or shooting stars as they rush through the upper air. These meteors become visible at altitudes as high as 120 miles, showing that at that elevation there are obstacles of a nature analogous to that of a resisting gas. In fact, as the meteors are burned up, we must acknowledge that the débris are perpetually making new additions to our atmosphere. So important is this question, both to astronomy and to meteorology, that the Astronomical and Astrophysical Society of America has lately started an inquiry as to what methods are available for photographing meteors and meteor trains, or what studies can give us any facts about the highest air. I understand Professor Woodward to state that there is a mechanical possibility of the existence of another atmosphere above that which affects our barometer, which therefore may revolve about the globe, like the rings of Saturn, in equilibrium within itself.

The most interesting definite problem bearing on the highest atmosphere relates to the cause and nature of the aurora borealis. These beautiful northern lights have been carefully studied by Swedes and Norwegians. Twenty years ago, all the nations of the globe united in a series of expeditions to both the arctic and antarctic regions for the study of magnetism, auroras and meteorology. Since that date four special expeditions have been sent northward by Norwegians, and the leader of these, Professor Birkeland, of Christiania, has developed some new views as to the aurora, that have been confirmed by the mathematical investigations of his colleague, Professor Stoermer. They have devised remarkable ways of continuous photography and accurate calculation of altitudes.[2] The publication of the details of their work has begun, and I think we may safely anticipate that future generations will busy themselves developing the ideas that are now being presented by these physicists. All that we need say at the present moment is that particles which we call ions (or, when they are electrified, electrons), pass with the velocity of light from the sun to the earth. If this be incredible, we must at least say that some influence passes from the sun to the earth, with the speed of gravity or the speed of light, causing electrons from space or from the celestial bodies to approach the earth's atmosphere with great speed. But no sooner do these come within the influence of the earth's magnetism (and that influence extends to great distances beyond the atmosphere), no sooner do the electrons feel this influence, than they are diverted from their straight-line courses and begin to describe curves surrounding the earth like spiral corkscrews. Whenever such particles enter certain gases (such as krypton), the gas becomes luminescent or phosphorescent, and gives us the auroral light. This hypothesis is sufficiently complex to allow of many uncertainties as to details. It is at present in its formative stage, but there is good reason to believe that we have here a solid base on which to build a structure that will carry us from the firm ground of experimental laboratory physics over into the equally firm, but unexplored region of mathematical cosmical physics.

[2] **One hundred and ninety miles were recorded on March 14, 1910.**

Let us come down from the highest atmosphere to some of the phenomena nearer the earth's surface. Possibly you may think that to the agriculturists the vital question is how to make it rain or how to stop the rain, according to the needs of the farmer. You may ask what are the ultimate causes of calamitous droughts, such as those of Syria, India and Australia, or the less injurious dry periods in Europe and America. These usually result from several successive years of deficient rainfall, as in the famous Biblical story of seven years of high water and seven years of low water, in the river Nile, in the days of Joseph. We have now many years of continuous record of the fluctuations of this great river and we know something of its irregularities. In order to understand why and when these droughts should occur, we must first understand how rain and snow are formed in the clouds and why rain does not always fall from the clouds. I have here on this laboratory table a small globe filled with the vapor of water mixed with air as it ordinarily occurs in the atmosphere. Now we know that when moist air rises up to the level of the clouds, it has expanded and by pushing aside the adjacent air has done work in its expansion. That work has used up some of the internal energy of the air which we call heat energy, so that the air has become cooler, just as steam expands and pushes the piston of a steam engine. When by this cooling the temperature of the moist air has been so reduced that it is near the dew-point, then the air is saturated with moisture and a cloudy condensation begins. This invisible vapor in the air begins to condense around every little particle of dust and every invisible electron. You have seen an ice pitcher covered with moisture on a warm summer day. In the same way these atmospheric dust particles are covered with moisture. I will now allow the air in this globe to expand by opening this lower stopcock leading to a low pressure chamber and you will notice the formation of a slight cloud of haze. The cloud is, however, not very dense because there is not much dust in the air. I will now repeat the experiment. First I will exhaust the air already in the globe, then close the lower stopcock. I wish to introduce into the globe more dust than is in the ordinary air of the room. To do so I light a match and hold it so that the smoke from the flame is near the upper end of the tube. When I turn the upper stopcock so that the vacuous space may become filled with air, the inrushing air carries the smoke in with it. I close the upper stopcock and now the globe is full of dusty moist air. I open the lower stopcock, this dusty air expands downward into the lower pressure chamber and you see a dense cloud of fog is formed. These successive steps illustrate the ordinary method of the formation of clouds, but not of rain. To understand that, we must go a step further. Thus far I have allowed the dusty moist air expanding downward to increase its volume in the ratio of 600 or 650 to 760, *i. e.*, 1 to 1.2 or 1.3. I will now enlarge the lower chamber so that the expansion may be in ratio of 500 to 760 or 1 to 1.5. Moreover, I will not allow any dust to enter the upper globe, but will draw into that globe dustless air filtered through this bit of cotton wool. If now I allow moist or saturated dustless air to expand into the lower chamber from the pressure 760 to that of 500 or an expansion of about 1.5 in volume then I shall form not a cloud of small particles, but a few larger drops of water. This is the process that must be going on within the thunder-cloud, or in fact inside any rain-cloud. Out of the great mass of moist air that makes up the whole cloud only a small proportion is free from dust and of that only a small portion expands rapidly enough to form drops of rain-water.

I think you will see that the firing of cannon or dynamite in order to make a great noise is not likely to form rain and in fact can not possibly bring it down. Neither can it prevent the formation of hail or rain. If we wish to avert heavy rain or hail we must either cut off the supply of moisture, or else prevent the rapid expansion, or else throw dust upward into the air to cause cloudy condensation instead of rain. Apparently this latter process is carried out for us in nature when great forest fires afford enough particles of smoke to provide for the cloudy condensation of the free moisture. From the great clouds of smoke that attend these forest fires we get no rain until after a long time the heat that is in the cloud is lost by radiation, or until larger drops are formed by further expansion.

Even the bombardment of a cloud by the explosion of dynamite within it is inefficient to produce rain, in part because no violent concussion can drive the cloud-particles together into large drops of rain, and in part because the explosive itself furnishes more dust particles and more nuclei of condensation and therefore produces clouds instead of rain. In the same way the bombardment of the clouds by means of vortex rings is inefficient.

I have here an apparatus for making vortex rings of air; you notice that a slight stroke on the rear side of this box drives forward a vortex ring of smoky air. It is a beautiful sight and very instructive in many ways, but the special form of cannon devised in Italy to send such rings of gunpowder smoke up into the clouds and break up the formation of hail does not usually send them higher than 1,000 feet; they break up long before they reach the clouds. We have no evidence that they ever reach them, or that they could have any effect if they did so. If they carry up much dust they ought to have a slight effect in producing cloudy condensation, and thus cutting off the formation of rain or hail. But this effect is certainly too slight to be appreciable in our statistics. I regret to think of so many thousands of farmers wasting time and money on this delusion. You know that De Morgan after spending much time in combating analogous delusions wrote an interesting volume classifying as "paradoxers" all those who believed in squaring the circle, or in perpetual motion, or that the world is flat, or that the sun do move. They can believe the impossible. It is the same way with those who expect great mechanical work to be done without the expenditure of a corresponding amount of force or energy. The law of the conservation of energy runs all through meteorology as it does through the mechanics of nature everywhere. Energy and work may be transformed to and fro, but never destroyed nor created by man.

I have no doubt that we shall some day long years hence acquire some control of the atmosphere, but at the present time we are not ready for it, neither scientifically nor socially. I say socially because if *A* could make it rain when his neighbor *B* wants dry pleasant weather, we should have grumbles and lawsuits and socialistic eruptions far worse than now.

I dare say that if ever we are to follow in the footsteps of Franklin who deprived lightning of its terror, or of Redfield who taught the mariner how to avoid the dangers of the storm-center, we must adhere closely to nature: when once we know the details of her methods, then we may hope to learn how to make or to prevent the weather. To this particular study of the formation of rain, John Aitken, of Scotland, Carl Barus, of Brown University, and C. T. R. Wilson, of Cambridge, England, have especially contributed by their laboratory experiments. It is a question on which meteorological observers and laboratory physicists must labor together.

In India the prediction of great droughts has long been held to be one of the most important questions that can be attacked by the weather bureau of that country, and eminent men have worked upon it for twenty years past. The progress of their studies has gradually led us to see that the moist air of the southwest monsoon from which the rain falls has come from an unexpectedly great distance, namely, from the southern Indian Ocean. As you see on this globe before you, during the Asiatic winter season we have northeast trade winds here, and southeast trade winds there, south of the equator; but in the Asiatic summer season the heated air of the great continent of Europe, Asia and Africa, produces such an immense disturbance that over a large portion of the Indian Ocean the southeast trade wind disappears, or rather is turned about and flows northward over the equator to the region of the northeast trade, which is also turned about, and both combine to feed the great southwest monsoon of Asia. Knowing the origin of this moist monsoon, we shall be able to determine the probability of droughts or rains in India when we know whether the supply of air is sufficient and whether it will flow over the right region, or whether it will be deflected away from India. But to settle this question is at present very difficult.

The flow of any current of air is determined largely by the pressure of other air on each side of it, and it is quite possible that the flow of the southwest monsoon, at any place and time, may be affected by something that occurred long before in a very distant part of the globe. At first it was thought that the condition of the snow lying on the ground in the Himalaya Mountains would determine the movement of the monsoon and the amount of rain in the lowlands, but, as I have elsewhere stated, the supply of air to the southern Indian Ocean must ultimately come from the great westerly winds of the roaring forties, and therefore the Asiatic circulation must be affected by the condition of affairs in south Africa and the south Pacific and even the south Atlantic oceans.

On November 14, 1896, simultaneous balloon ascensions were made from St. Petersburg and Munich and from intermediate cities, in the midst of an area of high pressure that was moving slowly eastward over Europe.[3] My study of these observations in the light of my maps of high-level isobars for the northern hemisphere[4] gave occasion for the following long range forecast which was made early in December,[5] and, of course, long before we received any reports from India. "As a result it is quite possible that this area may have brought to upper India light snow followed by cold dry weather about the first of December, 1896."

As this prediction was abundantly verified, as shown by the reports which we received a year later, it may be worth saying that the study of these upper isobars explains why the areas of high pressure over North America usually move at first from the northwest; subsequently their velocity diminishes while the path turns more nearly eastward; on the other hand, similar areas of high pressure and cold air in Europe are apt to come from the northeast before they turn southeastward.

It seems certain that the atmosphere is so mobile that whatever happens on one side of the globe will soon be known by its results on the opposite side. Whatever happens in the atmosphere fifteen miles above the earth will soon produce results at the earth's surface far away. Meteorology must embrace the whole atmosphere above and below, north and south, east and west.

I suppose that the most important problem of the present time is to attain a clear idea of the mechanics of the earth's atmosphere as a whole. We separate this problem into three closely related divisions. First we treat the atmosphere as we would a liquid of very rare but uniform density. Next we introduce the idea of a gas which enlarges or contracts in volume with every change of pressure or temperature.

Finally we pass from simple dry air and moisture to study the

[3] See *Monthly Weather Review*, November, 1896, p. 415.

[4] Published as chart VII. in that number of the *Review*.

[5] See p. 420 of that same number of the *Review*.

changes of volume and pressure and corresponding changes of temperature, moisture and cloud. These studies are comprised under the technical terms hydro-mechanics, aero-dynamics and thermo-dynamics. The atmospheric problems of to-day and of all future time will undoubtedly be concerned principally with these three classes of questions, and another century may elapse before men can solve them all.

I have here at hand a circular table which represents a small portion of our globe within the polar circle, while the center of the table represents the north pole itself. I will set the table in rotation; of course it revolves much more rapidly than the earth does. It is now revolving from left to right as the earth itself does when we stand facing the north and see the sun rising in the east. If I shoot this ball so that it rolls straight across the revolving table, it will not trace a straight line on that table but a curved line. If the track lie on the right-hand side of the pole the curvature will be toward the equator, but if on the left-hand side then the curve will be away from the equator. In both cases the curvature is toward the right hand as the ball progresses. This sentence corresponds to the two cases of a body moving, respectively, eastward or westward on the earth. When it moves eastward it has a greater centrifugal force than the corresponding point on the globe and pushes toward the equator. When it moves westward it has a less centrifugal force and retreats toward the pole. Corresponding phenomena occur when a pendulum is swung to and fro as in the Foucault pendulum experiment; or when a gyroscope is rapidly spun, as was also done by Foucault. We were long since taught by Poisson, Tracy and Ferrel that any mass, whether solid, liquid or gaseous, moving on the surface of the rotating earth in the northern hemisphere experiences a deflection to the right, and this is true under ordinary circumstances. Perhaps you will not be surprised to learn that our distinguished mathematical colleague, Professor Chessin, of Washington University, St. Louis, has lately reopened this question and even yesterday in this very lecture room showed that under some circumstances the deflection may be to the left, so that questions which have been considered settled for many years are now deemed worthy of a new investigation. Thus in meteorology we must expect to be frequently called upon to revise our old ideas in the light of the newest researches.

The study of hurricanes and typhoons long ago led to the general conclusion that they consist of comparatively thin layers of air revolving horizontally in nearly circular orbits, and therefore analogous to the revolving horizontal wheel of a gyroscope whose axis is vertical. On the other hand the phenomena of the waterspout at sea and the tornado on land had led to the idea that in these cases we have to do with nearly vertical ascending currents of air. Redfield's careful construction of numerous weather maps made him certain that in a hurricane the winds trend inward toward the center to such an extent that the hurricane can not be considered as a system of circular rotations, but of spiral inflowing ascending and overflowing currents of air, or the ideal cyclonic vortex movement. The same conclusion was soon formed with regard to the waterspout and tornado, the only differences being as to the question what are the angles of inflow, ascent and overflow? Since 1871 a still more careful analysis of the United States daily weather maps has shown that it is necessary to consider the fact that the winds on the west side are colder and drier than those on the east side of the storm center. Thus it follows that in the northern hemisphere we have cold dry northwest winds swirling around the central low pressure and running under the more moist southerly winds, sometimes even going so fast as to overflow these for short distances while pushing them aside. In this respect a hurricane storm lies intermediate as to its mechanism between the thunder-storm and the waterspout. In the waterspout we have a relatively small mass of air, no great differences of temperature, a rapid ascension with a rapid horizontal rotation. In the thunder-storm we have a simple horizontal overturning; cooler or drier air descends from overhead and warmer or moister air ascends from below. In every style of storm and in every form of atmospheric circulation there is and must be overturning with overflow and underflow.

The problems of simple overturning have been studied by Margules from the thermo-dynamic point of view. Perhaps I can illustrate these problems by means of this glass box with vertical divisions. I will place this dividing blanket in the middle. On the left-hand side we have a mass of air cooled by this adjacent ice; on the other side is an equal volume of air at the temperature of the room. If I quickly remove the blanket the cold air settles down, flowing beneath the warm moist air and covering the bottom, while the warm air is raised to the top. The differences of density have caused an interchange of energy due to the action of the force of gravity quite independent of radiation or conduction of heat. The descending cold air has expended some of the potential energy of its position in elevating the warm air. If the warm air was anywhere near the point of saturation, then its small loss of temperature due to its rising and expanding may have produced a haze in our little experiment, but in nature it often produces a great thunder cloud, and every gradation of cloud from that form down to the thinnest stratum.

These overturnings are perpetually going on in every room of our buildings and of course in the atmosphere. If a cloudy mass descends it is warmed by compression as it descends; evaporates all its cloudy particles, and in its further descent eventually has its own temperature raised. In general we have very low temperatures at great altitudes in the atmosphere, but if such air were brought down rapidly to the earth's surface it would be warmed up by compression so as to be insufferably hot and dry. This is the method of the formation of the hot, dry southwest winds of Kansas, Arkansas and Oklahoma where "corn is roasted on the stalk." Our North American cold winds from the northwest represent one step in the general condition of the whole atmosphere; they are undoubtedly descending winds, but descending so slowly and rolling along the earth to such great distances toward the equator that the air has time to cool by radiation before it reaches us. This is the formation of our areas of "high pressure" and cool, dry, clear weather.

In close analogy to the steam engine driven by heat that is derived from fire but is lost in the condenser, so the motive power in the atmosphere is the heat received from the sun, but lost by radiation from the earth. As to quantity and quality of this solar heat we are still at the beginning of our knowledge. Eminent authorities adopt figures ranging between two and four calories per minute per square centimeter. Every effort must be put forth to determine more accurately this fundamental datum.

Very many insist on searching our climatological records for periodic phenomena such as solar rotation periods and sunspot periods and lunar periods. Brückner's period of 35 years is quite famous. We have as yet very little data on which to base satisfactory researches into these questions, but the trend of our present knowledge is to show that in so far as these periods depend upon external or cosmical influences they are too feeble to be of importance; in fact, too feeble to be clearly recognized.

On the other hand, in so far as they depend on the internal mechanism of the atmosphere, they die out in a short time after they have been started, and are not permanent or steady periods in the proper sense of the word, but are driven and imposed on the atmosphere by conditions outside of it. Just as we see ripples standing in the rear of a stone in a shallow stream of water, so we have waves and clouds in the atmosphere on the leeward side of every obstacle. The annual periodic changes in the declination of the sun and in the resulting monsoons are undoubtedly accompanied by great reactions in our atmosphere extending like waves around the whole globe; but these again die out in a few years. Almost the only periodic phenomenon due to the internal mechanism of the atmosphere, one that is permanent and appreciable, is the semi-diurnal change of pressure which appears likely to be an internal phenomenon of resonance maintained by the regular diurnal change of temperature. But these questions are not settled and remain for further investigation.

I think the great climatic changes that seem to have taken place during geological history must be explained in connection with the corresponding changes that have taken place in the orography of the continents, and the changes in the distribution of land and water. The great gorges that extend from the Hudson through New York Bay toward the Middle Atlantic and from the Congo on the western coast of Africa also into the mid-Atlantic prove beyond controversy that there was a time when the ocean level was 5,000 feet lower than now, relative to the land on either side. Of course we know that mountain ranges have risen gradually by successive slight earthquake rifts; that the surface of the globe has always been cracking and bending, rising here and falling there. When we are able to demonstrate clearly the connection between our present climates and our present surface orography, then we shall be able to show what geological climate must have prevailed in any other age if the geologists can tell us what were then the characteristics of the surface. I consider this to be the ultimate end of meteorology, namely, the logical deduction of the climate and the weather for any time and any given configuration of continents and oceans. When we have attained this goal; when meteorology has become more truly deductive, then we can pass to the satisfactory discussion of the great problems that we now can merely toy with like children. Then we shall know whether Mars is inhabitable, and whether man could possibly have existed and evolved anywhere on this earth during geological ages preceding the present.

I am safe in saying that it is impossible to foresee in detail the problems of the future meteorology. I have by a few special cases illustrated the general conclusion that a long array of unsettled problems confronts those who would understand the operations of our earth's atmosphere. The fundamental problem of to-day is to educate men for the work that we see is at hand. Friends of science and humanity must be found who will provide for the expenses of men able to work on these problems. We need laboratories, physicists and sympathetic supporters. Perhaps the very first step is to provide generous fellowships, securing a support for enthusiastic men who are adapted to these researches. Atmospheric phenomena are not too difficult for us, nor is there any known natural limit to our steady intellectual progress. Those who are attentive to the voice of nature hear a command like that given to Joshua, "Go up into the land and possess it." But we also hear the voice that said unto Adam, "In the sweat of thy brow shall the earth bring forth its fruit." Whatever is worth doing involves hard work both physical and intellectual. We have many years of work before us, many abstruse and difficult problems, but what we ask first and last is your kindly sympathy and hearty support until success crowns the end.

KANT AND EVOLUTION

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II

IN the previous part of this article we have examined two of Kant's early writings, and have found in the one a confused mechanistic theory of cosmic evolution, and in the other a sort of anthropological and social evolutionism—neither doctrine being truly original with Kant himself. But we have discovered no traces of biological evolutionism, in the sense either of an admission of the possibility of the production of the organic out of the inorganic by natural processes, or in the sense of an assertion of the mutability of species. In the writings next to be considered we shall find Kant brought directly into the presence of the more fundamental questions of theoretical biology.

3. *The Two Essays on the Conception of "Race," 1775, 1785.*—The review of Moscati (1771), summarized in the preceding instalment of this survey, was the earliest indication among Kant's writings of a growing interest in a group of scientific problems which always thereafter much occupied his attention: namely, the genetic problems of physical anthropology. The beginnings of that science, in its systematic form, are usually credited to the treatise of Blumenbach, "De generis humani variatione nativa," 1775. Blumenbach, says the historian[21] of eighteenth century anthropology, "derived his zoological facts chiefly from Buffon. His philosophy, and in particular his fundamental conception of man's place in nature, were founded on the system of Leibniz. The opening sections of his book at once show his principal preoccupations in the inquiry—*viz.*, to establish the limits, on the one hand, between man and the animals, and, on the other hand, between the different races of men. These two remained the chief themes of anthropology throughout the succeeding period." It was to the second of these themes that Kant especially addressed himself. His first discussion of it appeared in the same year as Blumenbach's treatise. In the "preliminary announcement" to his "Lectures on Physical Geography," delivered in the summer semester of 1775, Kant took for his topic "The Different Races of Men";[22] he reverted to the subject in an article in the *Berliner Monatsschrift* for November, 1785, entitled

[21] Günther, "Die Wissenschaft vom Menschen im 18ten Jahrhundert," p. 287.

[22] "Von den verschiedenen Racen der Menschen." This writing will here be referred to as the "Physical Geography." It is to be found in Hartenstein's edition, 1867, II., 433.

"Elucidation of the Conception of a Race of Men."[23] These two essays do not significantly differ in doctrine, and they may most conveniently be dealt with here as slightly variant expressions of the same arguments and conclusions. They are among the most important documents for the determination of Kant's position with respect to the theory of evolution.

Kant derived not only most of his zoological facts, but also some of his ideas of scientific method, from Buffon. The latter, like Maupertuis, had ridiculed the "systems" and "methods" of the great systematists, Linnæus and Tournefort, and had looked with a good deal of contempt upon their absorption in purely descriptive and classificatory science. Schemes of classification were convenient, no doubt, and accurate description essential; but there was a higher stage of scientific inquiry to which these were merely vestibulary. Buffon wrote:[24]

> 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, to link them together by the force of analogy, and to endeavor to arrive at that high degree of knowledge in which one can recognize particular effects as dependent upon more general effects, can compare nature with herself in her larger processes.

This spirit Kant had in some degree caught; and in the "Physical Geography" he proposes a modification in the nomenclature of the sciences which should express the distinction between two types of scientific inquiry. He observes:

> We are accustomed to use the words "*Natursbeschreibung*" (description of nature) and "*Naturgeschichte*"[25] (natural history) as synonymous. But it is manifest that the knowledge of the things of nature as they now are still leaves to be desired a knowledge of what they previously have been, and of the changes through which they have passed in order to arrive at their present condition. A "history of nature"—such as is still almost completely lacking—would make known to us the alterations of the form of the earth and those which the terrestrial creatures (plants and animals) have undergone in the course of their natural migrations, and their consequent divergences from the primitive type of their ancestral species (*Stammgattung*). Such a science would probably reduce a great number of seemingly distinct species (*Arten*) to mere races of a single genus (*Gattung*), and would transform the now current artificial system (*Schulsystem*) of nature-description into a physical system for the understanding.

In this, manifestly, Kant shows a lively sense of the nature and importance of genetic problems in the investigations of the naturalist. It is true that he somewhat naïvely makes the distinction between the

[23] "Bestimmung des Begriffs einer Menschenrace," here referred to as the "Conception of Race." V. Hartenstein edition, IV., 215.

[24] "Discours de la manière d'étudier et de traiter l'histoire naturelle." In "Œuvres," Lanessan ed., Vol. I., p. 6.

[25] Later (in the "Use of Teleological Principles") Kant proposed to express this distinction by the words "physiography" and "physiogony."

genetic and the descriptive equivalent merely to the distinction between past and present. It need hardly be said that genetic inquiries in science are not necessarily purely historical or archeological inquiries, since phenomena of genesis may be recurrent phenomena, taking place in accordance with the same laws in past or present. But, though he blurred the idea somewhat, it remains true that, in his contrast between two types of scientific research, Kant exhibited his inclination to what, in the vaguer sense, may properly be described as an evolutionary habit of mind. It still remains, however, to determine just how far this carried him, when he came to the consideration of definite problems.

His problem of predilection, as I have said, was that of the nature of a "race," the relations of different races, and the causes of their diversity in physical characters. And this made necessary, at the very outset, a consideration of the nature of a "species." Here, once more, Kant follows Buffon: "Animals, however different they may be in form, belong to the same physical species if, when mated with one another, they produce fertile offspring."

> This Buffonian rule gives a definition of natural species as such (*die Definition einer Naturgattung der Tiere überhaupt*), in contrast with all artificial species (*Schulgattungen*). The artificial classification deals with *classes*, which are grouped together upon the basis of similarity, the natural classification deals with lines of descent, grouping animals according to blood-kinship. The one provides an artificial scheme to aid the memory, the other a natural system for the understanding. The purpose of the former is merely to bring animals under labels, that of the latter is to bring them under laws.

These references to *Naturgattungen*, determined by the criterion of fertility of offspring, are themselves hardly in the language of transformism. Yet one who employed such language might still regard these "true species" as eventual results of divergent descent from common ancestors. But when we examine Kant's way of further defining these species, we find that his notion of them expressly precludes the possibility of any transformation of one into another through descent. By the Buffonian test, he says:

> All human beings belong to one and the same natural species, since in mating they always beget fertile offspring, however dissimilar the parents may be in appearance. For this unity of natural species there can be but one natural cause, *viz.*, that all men belong to a single stock (*Stamm*), from which they have originated or at least could have originated. In the former case [*i. e.*, of actual descent from common ancestors], they belong not only to one and the same species, but also to one family; in the latter case they would be similar to one another but not related, and it would be necessary to assume a number of separate local creations: an opinion which multiplies causes beyond necessity.[26]

[26] The same ideas are perhaps still more clearly expressed in the article "On the Use of Teleological Principles in Philosophy," 1788: "There could be no more certain test of diversity of stock (*des ursprünglichen Stammes*) than the inability of two different hereditary branches of mankind to engender fertile

This argument, by which Kant reasons that all men are of one *Stamm,* directly implies that men and other animals are *not* of one *Stamm, i. e.,* are not related through any lines of natural descent. For he makes identity of species synonymous with community of descent, and diversity of species synonymous with separateness of descent. In other words, his manner of distinguishing a species from a race rests upon wholly anti-evolutionary presuppositions.

Within the limits of a species, however, Kant holds that very considerable modifications of physical character may be brought about in the course of successive generations. Now (apart from individual variations not transmitted to offspring), there seem to Kant to be two significantly different types of heritable peculiarities: those which are *invariably* inherited, and those which are only *alternatively* inherited. Thus the colors of a negro and a white who marry are both manifested in the offspring; children of such marriages are always mulattoes. But the complexions of the children of a dark man and a blonde woman are not necessarily a compromise between the complexions of their parents. Some or all of the children may resemble one parent only, and show (with respect to any given character) no marks of their descent from the other. By means of this distinction Kant differentiates a "race" from a "variety." Those members of a single species which also possess in common characters of the invariably hereditary sort belong to the same race; those which possess in common (and, so long as they mate with their own like, transmit to their offspring) characters that, upon cross-breeding with other types, are only alternatively hereditary, constitute only "varieties."

These definitions of "species" and "race," it is true, involve—as Kant recognizes—some revision of the classifications of the systematists.

> Originally, when only similarity and dissimilarity were taken into consideration, it was customary to group classes of creatures under *genera* (*Gattungen*). But if it is their descent we are considering, it is necessary to ask whether these classes are species (*Arten*) or only races. The wolf, the fox, the jackal, the hyena and the domesticated dog, are so many classes of quadrupeds. If one assumes that each of them has a special descent (*Abstammung*), they constitute so many species; if one grants that they may have sprung from a single stock, they are simply races of that stock. In "natural history" (*Naturgeschichte*), which has to do only with generation and descent, the words *Art* and *Gattung* mean the same;[m] only in "nature-description," where it is merely a question of the comparison of characters, does a distinction between

offspring. But where the generation of such offspring is possible, the utmost diversity of external appearance is no obstacle to regarding the parents as having a common descent. For if they can, in spite of this diversity, produce offspring that exhibit the characters of both parents, then they may be classified as belonging to two *races* of a single stock, which originally had latent within itself the characters that were to be developed in each separately."

[m] It is for this reason that, in translating Kant's expositions of his own doctrines, I have, so far as possible, rendered both *Art* and *Gattung* by "species." The citation is from the "Conception of Race," § 6, *n.*

them find place. What in the latter is called a species must in the former often be designated as a race.

Kant's elaboration of an ethnological scheme upon the basis of these definitions does not here concern us. But it is worth noting that he finds that the only character which is "invariably inherited" from both parents—and therefore the only mark of a true or "natural" race—is skin-color; and that, using this criterion, he finds that there are just four races of men, the white, the negro, the Mongolian or "hunnish" and the Hindu. From these four originals Kant was prepared to explain all the hereditary shadings of the various peoples of the earth as the results of diverse hybridizations. The question of greatest interest of all, from the standpoint of biological theory, still remained to be asked. Within the limits of a "natural species," we have seen, Kant recognized that profound modifications of physical characters took place, and became permanent and transmissible through heredity. Thus, he thinks it at least a probable conjecture that the original type of man was white. But from white ancestors black and yellow and brown races have been developed. How did this come about? What, in Kant's words, are "the immediate causes of the origination of these different races"? He has his own entirely confident answer to the question. A natural answer for an eighteenth-century biologist would have been to say that these differentiated racial characters are the results of environmental modifications of individuals, which gradually have become hereditary. But such an explanation Kant emphatically rejects. It would hardly do to call him an eighteenth-century Weismannist; but he was (though not without serious but unrecognized inconsistencies) a vigorous opponent of the supposition that acquired characters can be inherited, and an unqualified partisan of the doctrine of the continuity and unmodifiability of the germ-plasm. His reasons for taking this position betray once more his entire inability to conceive of the transformation of "real" species into other species.

There are current, he admits,[28] many, though poorly authenticated, stories of cases in which acquired characters have been inherited: tales of the "influence of the imagination of pregnant women" upon the fœtus; of "the plucking out of the beard of entire peoples, and of the docking of the tails of English horses, by which nature was compelled to eliminate from the processes of reproduction in these organisms a product for which those processes were originally organized"; accounts of "the artificial flattening of the noses of new-born infants, which peculiarity nature is supposed finally to have taken up into the reproductive faculty." Kant rightly regards all such stories with a sceptical eye; but his theoretical reasons for doing so are significant. These accounts are to be rejected because they conflict with a general

[28] "Conception of Race," § 5, and *Anmerkung*.

principle or presumption of science which must be adhered to at any cost, namely:

that throughout organic nature, amid all changes of individual creatures, the species maintain themselves unaltered (*die Species derselben sich unverändert erhalten*)—according to the formula of the schools, *quaelibet natura est conservatrix sui.* Now it is clear that if some magical power of the imagination, or the artifice of men, were capable of modifying in the bodies of animals the reproductive faculty itself, of transforming Nature's original model or of making additions to it, which changes should then become permanent in subsequent generations, we should no longer know from what original Nature had begun, nor how far the alteration of that original may proceed, nor—since man's imagination knows no bounds—into what grotesqueries of form species might eventually be transmogrified (*in welche Fratzengestalt die Gattungen und Arten zuletzt noch verwildern dürften*). In view of this consideration, I for my part adopt it as a fundamental principle to recognize no power in the imagination to meddle with the reproductive work of Nature, and no possibility that men, through external, artificial modifications, should effect changes in the ancient original of a species in any such way as to implant those changes in the reproductive process and make them hereditary. For if I admit a single instance of this sort, it is as if I admitted the truth of a single ghost-story or tale of magic. The boundaries of reason are then once for all broken through, and errors rush in by thousands through that opening. There is, meanwhile, no danger that, in adopting this conclusion, I may take a position of blind or stubborn incredulity towards real facts of experience. For all these romantic (*abenteuerlich*) occurrences have without exception one peculiarity, namely, that they can not be subjected to experiment, but are supposed to be proved merely by casual observations. But whatever, though capable, indeed, of experimental testing, offers no experimental evidence, or employs all sorts of excuses to avoid such a test, is mere fiction and illusion.[29]

Nothing could better exhibit Kant's characteristic state of mind on biological questions than this passage. There are occasional bits of sound sense in it and of discriminating judgment about scientific method; and there is a certain power of at least seeing where the significant problems lie. Yet, though he had come under the influence of evolutionistic conceptions, and is in these very writings endeavoring to apply genetic methods to certain biological inquiries, he recoils in horror before the idea of admitting that real species are capable of

[29] The "Physical Geography" is equally emphatic in repudiating both inheritance of acquired characters and mutation of species: "External things may, indeed, provide the occasions, but they can not be the efficient causes, of the appearance of characters that are necessarily transmitted and inherited. As little as chance or physico-mechanical causes can bring an organic body into existence, just so little can they imprint anything upon the reproductive faculty, that is, produce any effect that is itself reproduced, either as a special form or as a relation of the parts. Air, light and nutrition can modify the growth of an animal body, but they can not furnish this change with a power of reproducing itself after its original causes are no longer operative. . . . For it is not possible that anything should so penetrate into the reproductive faculty as to be capable of gradually removing the creature from its original determination and bringing about a real and self-perpetuating departure from the specific type (*Ausartung*).

transformation. It is primarily in the name of a pseudo-axiom of scholasticism that he pronounces for the fixity of species! But in reality, as his expressions show, it was because of certain temperamental peculiarities of his mind—a mind with a deep scholastic strain of its own, one that could not quite endure the notion of a nature all fluent and promiscuous and confused, in which series of organisms are to an indefinite degree capable of losing one set of characters and assuming another set. He craved, after all, a universe sharply categorized and classified and tied up in orderly parcels. And thus, though he had learned from the newer scientific tendencies of his time that the business of science is with processes, and especially with genetic processes, this scholastic side of his mind prevented him from making any thorough application of the principle to biology. He was prepared to go a considerable distance upon the path of evolutionism—but to admit that organisms (always to Kant, because of their "teleological" character, forming in nature a realm apart) were so far plastic that the very archetypal traits of species could, under the play of ordinary, environmental agencies, be altered past recognition—that was too much!

Meanwhile, it must be remembered that he was already committed to the admission of a large measure of modification within the species. But if it were so incredible a thing that the "original form" of a species should be radically altered, why was it not equally incredible that black men should be descendants of white men? Why did not the arguments against the transformation of one species into another species apply equally to the transformation of one race into another race? Why should one who supposed—as Kant supposed—that the wolf or hyena may have developed into the extraordinarily diversified breeds of our domestic dogs, have found it an intolerable paradox to suppose that the horse may have developed into the donkey, or both from a common ancestor? To such questions as these Kant's theory concerning the causes of the origination of races was called upon to provide an answer. The answer has an appearance of great simplicity: Kant merely said that in reality races had no characters which were not present, *but latent,* in their species from the start. In other words, he escapes the difficulties of his position by the easy artifice of a hypothesis of preformations. Nothing has been added to or taken from the germ-plasm of the species "man" since the beginning; the reproductive faculty merely contained in itself always certain alternative potencies—especially with respect to the production of skin-color—one or another of which was called into play in accordance with variations of external circumstances.

Any character that was to be transmissible (*was sich fortpflanzen soll*) must have already lain beforehand in the reproductive faculty, predetermined to develop at the proper occasion, in conformity with the circumstances amid which the animal might find itself and in which it would be obliged to maintain itself. . . . This precaution of Nature to equip all her creatures for all kinds of future conditions by means of hidden inner predispositions, by the help of which they may maintain themselves and be adapted to diversities of climate or soil, is truly marvelous. It gives rise, in the course of the migration and change of environment of animals and plants, to what seem to be new species; but these are nothing more than races of the same species, the germs and natural predispositions for which (*deren Keime und natürliche Anlagen*) have developed themselves in different ways as occasion arose in the course of long ages.[30]

Kant's conception of the "grounds" for the existence of these *Anlagen* is manifestly teleological in the most *naïve* way; the species was fitted out beforehand with distinct elements in its germ-plasm in order to furnish its later representatives against specific contingencies that had not yet arisen, and in some cases never would arise. This idea Kant elaborates in detail in the case of the skin-color of the negro; the passage is so delightful a combination of teleological "explanation" and phlogistic chemistry[31] that it deserves to be quoted:

The presence of purposiveness in an organism is the general ground from which we infer an original preparation in the nature of a living being, having this [purpose] in view, and—if the purpose is only later fulfilled—infer the existence of duly furnished germs. Now, this purposiveness can be in no race so clearly shown as in the negro. . . . It is already known that human blood turns black simply through becoming overcharged with phlogiston (as may be seen from the under side of a cake of blood). Now the strong odor of the negro, which can not be removed by any degree of cleanliness, already leads us to surmise that his skin eliminates a great deal of phlogiston from the blood, and that Nature must have so organized his skin that it is capable, in much greater degree than is ours, of dephlogisticating the blood—this being, with us, accomplished chiefly by the lungs. But the true negroes live in lands where the air, because of the thickness of the trees and the marshiness of the surroundings, is so heavily phlogisticated that, according to Lind's account, English sailors run the risk of death from this cause when they ascend the river Gambia even for a single day, for the purpose of procuring meat. It was, therefore, a very wise arrangement of Nature so to organize the skin of the negroes that their blood, even if the lungs do not sufficiently eliminate phlogiston, is yet far more thoroughly dephlogisticated than ours. Their blood must therefore deposit a great deal of phlogiston in the ends of the arteries, so that at this place—that is to say, just under the skin—it shows through as black, though in the interior of the body it is red enough.

Such, then, are reasons why our African brother is black and has a distinctive odor.

Kant's principles of the fixity of the specific type and the essential unmodifiability of the "reproductive faculty" imply that the diverse heritable and adaptive characters of what he calls "varieties," no less than those of races, preexist in the species ready-made from the outset, in the form of special "germs" or *Anlagen*. In writing the "Physical Geography" and the "Conception of Race" Kant does not seem to have

[30] Cited from the "Physical Geography."

[31] Kant was, of course, by no means abreast of the best chemistry of his time. The passage cited was published two years after Lavoisier's direct and decisive refutation of the phlogiston theory.

clearly perceived this implication; but in his essay "On the Use of Teleological Principles in Philosophy," 1788, he expressly draws the inference.

As for what are called varieties in the human species, I remark only that in respect to these, as well as to the racial characters, nature must be conceived, not as producing forms with entire freedom, but as merely *developing* forms in a way predetermined by original predispositions (*Anlagen*). For varieties (as well as races) show purposiveness and adaptation, and therefore can not be the work of chance. . . . The varieties among men of the same race were in all probability no less purposively implanted in the original stock (*Stamm*), in order to make possible the utmost diversity for the sake of endlessly various ends, than were the differences of race, in order to assure adaptation to fewer but more important ends. . . . There is, however, this difference, that the racial *Anlagen*, once they had developed—which must have already happened in the earliest period—no longer produced any new forms, nor yet permitted the old ones to become extinguished; while the *Anlagen* of varieties—at least so far as our knowledge goes—seem to indicate a nature inexhaustibly productive of new characters, both inner and outer.

It is a conventional practise, especially among German writers on philosophy, to speak in a tone of reverent admiration of Kant's profound insight into the spirit and methods of empirical science. The reader, therefore, will do well to note the precise logical character of Kant's procedure in framing and supporting these hypotheses, which constitute his special contribution to biology. In the first place, he assumes, with no evidence at all, that two species incapable of producing fertile offspring when mated, thereby testify that they can have had no common ancestors. He thus, with a single dogmatic phrase, "there can be only one cause of this" infertility, begs the entire question of the transformation of species, which had been already raised in his time by writers of the first eminence, whose work was well known to him. Further, in order to reconcile his doctrine of the impossibility of any real modification of nature's "original model" for each species with his doctrine of the descent of widely divergent races and varieties from a single species, he invented the hypothesis of the latent pre-existence of "germs" anticipatory of the subsequent changes of *milieu* which the species was to undergo, and destined to take command of the reproductive process when the proper occasions arrive, while the other germs obligingly retire into inactivity.[32] This, which remained to the end of his days one of Kant's most cherished notions, had most of the faults of which a scientific hypothesis is capable; and it had not even the ambiguous merit of serving the purpose for which it was designed. It was intended as a support to the anti-evolutionistic dogma which Kant had made his own: "every natural kind remains true to its original nature"; yet it was admittedly consistent with an

[32] Cf. "On the Use of Teleological Principles": "Wherever the ancestors of a race accidentally came and persisted, there was developed the germ latent in their organization with special reference to that neighborhood (*Erdgegend*) and capable of adapting them to that climate."

immense and indefinable degree of divergence, on the part of the descendants of a given pair, from the characters of their ancestors. As Kant himself observed, it assigned many of the species of the systematists to a common descent. But if the "reproductive faculty" of the primeval wolf was—as Kant grants that it may have been—capacious enough to contain special "germs" for the subsequent production, not only of wolves, but also of jackals, pug-dogs, greyhounds, dachshunds, hyenas and bull-dogs, there appeared to be no adequate reason for assigning any particular limit to the original capacity, and the consequent eventual versatility, of that faculty in any organism whatever. It was entirely open to Kant, without abandoning his theory of anticipatory germs, to regard the wolf in turn as the development of a germ implanted in still earlier ancestors, which the wolf and his diverse present progeny share in common with a group of organisms still more various; and so on *ad indefinitum.* Since the immutability of "nature's original model" was to be sufficiently salved by the simple device of supposing that model to have virtually contained within itself, and in course of time, under changing external conditions, to have extruded from itself, a vast assortment of other extremely dissimilar models, there was nothing in the most thorough-going theory of the transformation of species which could be inconsistent with an immutability of so elusive and so elastic a character. Kant's rejection of evolutionism was thus not justified even by those singular embryological speculations into which his desire to reject that theory seduced him.

4. *The Review of Herder's "Ideen."*—In 1785 Kant published a review of Herder's "Ideen zu einer Philosophie der Geschichte der Menschheit." Herder, as I have elsewhere shown,[33] was not a believer in the transformation of species; but he may perhaps be without exaggeration described as a near-evolutionist. He set forth in the "Ideen" the theory of a gradual production of organisms in an ascending series in which little by little the form and powers of man were approximated. Through all this "graded scale of beings" was conspicuous that "unity of type" which the work of Daubenton and Buffon in comparative anatomy had brought to light. The successive emergence of ever higher forms Herder ascribed to some innate potency in "nature" tending to progress and to the constant increase and diversification of life. Just how he conceived this to operate in the actual formation of organisms it seems impossible to make out; one is obliged to doubt whether he ever framed any definite ideas on the subject. But on the unity, yet inexhaustible diversity, of nature's productive power, and on the strange way in which, as he supposed, all animals and plants, and perhaps even snow-flakes and other inorganic things, are fashioned after a single archetype of form, Herder had much to say that was eloquent and impressive, if not very clear. In

[33] POPULAR SCIENCE MONTHLY, August, 1904, p. 327.

reviewing the book, therefore, Kant was naturally led to touch upon the subject of organic evolution. The passage runs as follows:

> As for the graded scale (*Stufenleiter*) of organisms, one can not so severely reproach the author because it will not consent to extend far enough to match those conceptions of his which reach far beyond the limits of this world. For the use of it even in relation to the kingdom of nature here on earth likewise leads to nothing. The slightness of the degrees of difference between species is, since the number of species is so great, a necessary consequence of their number. But a *relationship* between them—such that one species should originate from another and all from one original species, or that all should spring from the teeming womb of a universal Mother—this would lead to ideas so monstrous that the reason shrinks from before them with a shudder. Such ideas can not with justice be imputed to our author.

It is surely one of the humorous incidents in the history of science that more than one grave historian should have found, in the writings of this very period when Kant repudiated evolutionism with the tremulous emotion of a child frightened by a hobgoblin, the idea of evolution playing "the same rôle as in contemporary science."

5. *The Essay "On the Use of Teleological Principles in Philosophy."*—To the title of this article, published in 1788, the contents do not altogether closely correspond.[34] Part of it is, indeed, a prelude to the examination of the conception of purposiveness in nature given two years later in the "Kritik of Judgment"; but a greater part consists in a defence of the theories of his two papers on the idea of race against certain critics. For the purposes of the present inquiry those theories have already been sufficiently expounded. But it is worth while noting that, in the case of one of his critics, Forster, Kant supposed himself to be confronted with a definite evolutionary theory, upon which he felt obliged to pass judgment. The articles of what Kant understood to be Forster's "system" were these:

> The earth in travail, giving birth to animals and plants from her pregnant womb, fertilized by the sea-slime; a consequent multiplicity of local originations of organic species, Africa having its own separate species of men (the negroes), Asia another, and so on; as a deduction from these assumptions, the relationship of all organic species in an imperceptibly graded series, from man to the whale, and so backward (conjecturally even to the lichens and mosses)—and a relationship not of similarity merely, but of actual derivation from a common stock.[35]

[34] There is a reference to the species question in a fragment in the "Lose Blätter" (I., 137 f.), assigned by Reicke to 1787. This is probably merely a draft for part of the essay here considered. The fragment is in the usual vein; Kant speaks in it, for example, of "the inconceivable constancy of species, in the midst of so many causes affecting them and modifying their development."

[35] Kant's language clearly seems to ascribe these ideas to Forster, but quite without justification from anything in Forster's article. So far from fathering this system, Forster mentions it as an example of an over-ambitious hypothesis, beyond the reach of verification by man, and therefore beyond the limits of true science ("Teutsche Merkur," 1786, pp. 57–86, 150–166). And in his "Kleine

On this Kant remarks as follows:

These ideas will not, indeed, cause the investigator of nature to shrink back from before them with a shudder, as from before a monstrosity[30] (for there are many who have played with them for a time, though only to give them up as unprofitable). But the investigator *will* be frightened away from them upon a serious scrutiny, by a fear lest he be lured by them from the fertile fields of natural science to wander in the wilderness of metaphysics. And for my part I confess to a not unmanly terror in the presence of anything which sets the reason loose from its first and fundamental principles and permits it to rove in the boundless realms of imagination.

Kant's alarm, it is evident, was aroused by all three of the hypotheses which he ascribed to Forster. But he particularly disapproved of any attempt to inquire into the origin, the laws of genesis, of organisms in general, or of the original "stock" from which any species is descended. Such inquiries "lie beyond the province of any possible physical science." For science is competent to discover only relations of efficient causation; but organisms, being material systems "in which every part is at once cause and effect of every other part," admit only of "a teleological, not at all of a physico-mechanical, mode of explanation."

6. *The "Kritik of Judgment."*—The principal source of the belief that Kant was an evolutionist in biology is a celebrated passage in the "Kritik of Judgment" (1790), § 80. This passage is, unfortunately, usually quoted with its most important part—an appended foot-note—omitted. That Kant's true position may clearly appear (in so far as a position which is involved in a scheme of elaborate self-contradictions can ever be clear), it is necessary to cite the text here nearly in full:

It is praiseworthy to go through the great creation of organized natures with the aid of comparative anatomy, in order to see whether there may not be in it something resembling a system, even in the principle of generation of such beings. For otherwise . . . we are obliged to give up in discouragement all pretension to *natural insight* in this field. The agreement of so many species of animals in a certain common plan which appears to underlie not only their skeletal structure but also the arrangement of their other parts—so that, upon the basis of an original outline of wonderful simplicity a great variety of species could be produced merely by the shortening of one member and the lengthening of another, the diminution of this part and the elaboration of that—all this gives our minds a ray, though a feeble ray, of hope that something may here really be done with the principle of the mechanism of nature—apart from which there can be no natural science as such. This similarity of forms—so great that, amidst all their diversity, they seem to have been produced according to a common original type—gives force to the surmise of an actual relationship between them, by virtue of their generation by one primal mother (*Urmutter*) —through the gradual approximation of one animal species to another, from that in which the principle of purposiveness seems best established, *i. e.*, man,

Schriften," III., p. 335, Forster emphatically asserts the immutability of "the principal features of the primitive form (*Urbild*) of every species."

[30] Kant refers to a passage of Forster's in which these expressions are jestingly used. But, as it happens, they were originally Kant's own expressions, occurring in the review of Herder's "Ideen," already cited.

down to the polyp, and from this even to the mosses and lichens, and, finally, down to the lowest stage of nature known to us, namely, to crude matter; from which matter and its forces, according to mechanical laws, . . . the entire system of nature (which in organized beings is to us so incomprehensible that we feel constrained to think another principle for it) seems to descend.[37]

Here it remains open to the *archeologist of nature* to derive from the surviving traces of her earliest revolutions, according to any natural mechanism known to him or conjectured by him, the whole of that great family of creatures (for so we should have (*müsste*) to think of it, if the above-mentioned relationship is to have any ground). He can suppose the womb of Mother Earth . . . to have given birth at first to creatures of less purposive form; these in turn to have brought forth others (*diese wiederum andere* [*Geschöpfe*] *gebären lassen*) better adapted to the places where they originated and to their relations with one another; until finally Nature's womb, grown torpid and ossified, produced only species that underwent no further modifications; so that the number of species from that time forward remained just what it was at the moment when Nature's potency in the production of forms reached its end. Only, he must still in the end ascribe to this universal mother an organization purposively predisposed for the production of all these creatures. Otherwise the purposiveness of form characteristic of the products of the animal and vegetable kingdoms would be inconceivable.

Now this passage, though it painstakingly avoids all positive affirmation, doubtless sounds as if Kant intended by it, if not to indicate his own conversion to transformism, at least to issue to others a dispensation to embrace that doctrine. But the following note, attached to the end of the second paragraph, puts a different face upon the matter:

We may call a hypothesis of this kind a daring adventure (*ein gewagtes Abenteuer*) of the reason; there are doubtless few investigators of Nature, even of the most acute minds, to whom the hypothesis has not at times presented itself. For *absurd* it is not—in the sense in which *generatio æquivoca*—the production of an organized being through the mechanism of crude, inorganic matter—is absurd. It would after all be a case of *generatio univoca*, in the most general sense of the word, since the hypothesis supposes that every organism is derived from another organism, though the one may differ from the other in species; as if, for example, certain water-animals transformed themselves little by little into marsh-animals and these in turn, after some generations, into land-animals. *A priori*, in the judgment of reason alone, there is nothing self-contradictory in this. Only, experience shows no example of such a thing. According to experience, all generation is not only *generatio univoca* (in contrast with generation of the organic out of the inorganic), but also *generatio homonima*, in which the parent produces progeny having the same organization as itself. *Generatio heteronima* [*i. e.*, transformation of species], so far as our knowledge of Nature through experience reaches, is nowhere found.

This is certainly not the language of a believer, still less that of an advocate. True, Kant's position has significantly changed since two years previous. He has at last fairly discriminated the question concerning transformation from that concerning equivocal generation, and

[37] The entire hypothesis mentioned down to this point, it will presently appear, Kant really rejects as not only untrue but absurd. For it is a hypothesis implying "equivocal generation" and the reducibility of organic processes to mechanical laws.

has learned that the admission of a common descent of different organic species is not necessarily inconsistent either with his hypothesis of "purposive predispositions" or with those doctrines of the completely teleological character of organisms, and of their independence of all merely external causes of modification, which that hypothesis was designed to safeguard. He no longer condemns transformism on *a priori* grounds as a philosophical monstrosity. Its truth or falsity becomes a question to be settled by empirical evidence. But he also appears to say as plainly as possible that all the known empirical evidence is against the theory. No contemporary of Kant's, reading this passage in the "Kritik of Judgment" as a whole, was likely to find in it encouragement to risk that "bold adventure of the reason" of which it speaks. Moreover, in the next section of the "Kritik of Judgment" (§ 81) Kant, in discussing various embryological hypotheses, unmistakably gives his own endorsement to the opinion that "the Supreme Cause of the world . . . would, in the original products of its wisdom, have supplied merely the predispositions by which an organic being produces another of like kind and the species perpetually maintains itself." Throughout the remarks upon embryology contained in this section Kant seems to take the constancy of specific forms for granted.[38]

The chief topic of this second or biological part of the "Kritik of Judgment" is, of course, that question which had been present to Kant's mind ever since his adoption of a theory of the evolution of the inorganic world "according to mechanical laws." Could organisms also be mechanistically "explained," or only teleologically? It would require too much space to set forth and discuss adequately Kant's extremely diverse utterances on this question in his last important treatise. But when all those utterances are considered together, they do not seem to indicate any essential departure from the position which we have found him all along maintaining. It is true that he now insists with the utmost emphasis that without the conception of mechanism there is no such thing as science. "It is infinitely important for reason, in its explanation of Nature's processes of production . . . not to pass beyond the mechanism of Nature" (§ 78). He even declares that "apart from causality according to mechanical laws organisms would not be products of Nature at all" (§ 81). But he also continues with equal emphasis to insist that "absolutely no human reason (in

[38] Brock in commenting upon § 80 of the "Kritik of Judgment" observes that Kant takes cognizance directly only of the hypothesis of saltatory mutation, and is silent concerning the possibility of transformation through the summation of slight individual variations. This remark seems to me scarcely justified by Kant's language. By *generatio heteronima* he means the change of one species "little by little" (*nach und nach*) into another; though he evidently had only vague ideas of the rate at which, and the mode in which, this change might be supposed by the partisans of transformism to take place. (Cf. Brock in *Biol. Centralblatt*, Bd. 8, p. 644.)

fact, no finite reason like ours in quality, however much it may surpass it in degree) can hope to understand the production of even a blade of grass by mere mechanical causes. . . . It is absolutely impossible for us to derive from Nature itself grounds of explanation for purposive combinations," such as living beings are (§ 78). In short, we *must* regard organisms as part of the cosmic mechanism; and we *can not* so regard them. How these two assertions are to be harmonized is a thing "which our reason does not comprehend. It lies in the supersensible substrate of Nature, of which we can determine nothing positive, except that it is the being-in-itself of which we merely know the appearance" (§ 81). Kant, in short, had by this time acquired the vicious habit of affirming both sides of a contradiction and leaving it to "the supersensible" to reconcile them. Passages from the last "Kritik" may therefore be cited which seem to conflict with his earlier assertions of a sheer gap between the inorganic—the realm of mechanism—and the organic—the realm of teleology. But equally copious, or more copious, repetitions of those assertions may also be found. And upon the definite question of the possibility of "equivocal generation," Kant, as the foot-note already cited shows, remained true to his often-repeated opinion; the very notion of such a thing was to him an absurdity.

7. *The "Anthropology" of 1798.*—In his seventy-fourth year Kant returned to the subject of anthropology. His "Anthropologie in pragmatischer Hinsicht" does not, indeed, deal chiefly with the questions to which his earlier anthropological writings are devoted; the greater part of it is a rather miscellaneous but not uninteresting combination of his "critical" psychology and ethics with the purely temperamental convictions, tastes and prejudices of a septuagenarian bachelor professor, on matters of every-day life and social intercourse. Thus we find laid down, quite as a maxim of applied science, the practical observation that "eating alone (*solipsismus convictorii*) is not healthy for philosophers," though relatively harmless for mathematicians and historians. Any *philosophirende Gelehrten* inclined to the practise of dining in solitude will surely desist when they learn that they are thereby falling into *solipsismus convictorii.* The "Anthropologie" contains, however (in a footnote), one curious passage which has sometimes been quoted as evidence of Kant's acceptance of transformism. The human infant, Kant observes, comes into the world with a cry. This is characteristic of no other animal; and since it must, so long as man remained in the wild state, have been dangerous to both mother and child (by inviting attack from other animals),

We must suppose that in the primitive epoch of nature with respect to this class of animals . . . this outcry of the new-born was unknown, and that there subsequently supervened a second epoch, in which both parents had attained the degree of civilization necessary for the household life. . . . This remark carries us far; for example, it suggests the thought whether this second epoch might not, on the occasion of some great revolutions of nature, be followed by a third —an epoch in which an orang-outang or a chimpanzee should perfect the organs which serve for walking, touching, speaking, into the articulated structure of a human being, with a central organ for the use of the understanding, and should gradually develop itself through social culture.

Only to a superficial reading can this passage exhibit Kant in the guise of an evolutionist in biology. For, in the first place, there is no indication that he conceives even these extensive modifications of form and function as transforming the animals of which he speaks into new "natural" species, in his own sense of that term. In the second place, the passage does not suggest that the *existing* human species is descended from the apes. For in the "second epoch" mentioned, we already find our human ancestors living the household life; and the "third epoch," characterized by such striking improvements in the orang-outang and the chimpanzee, is subsequent to the second, and, in fact, still in the future.[39] Finally, even to this hopeful anticipation of a "good time coming" for the apes at some future "revolution of nature," Kant does not really subscribe; he merely expresses some passing wonder whether something of the sort "might not" occur. As a matter of fact, his publication of so vague and inept a passage as this after Maupertuis, Buffon, Diderot, Erasmus Darwin and Goethe[40] had written, shows that in his declining years he had not lost that constitutional aversion from the proper hypothesis of organic evolution which we have found to be characteristic of him from the beginning of his career. Also from the beginning, it is true, we have seen in him, as we see here, a constant vague inclination towards evolutionistic modes of thought. But through all that half-century, which constituted the period of the true beginnings of biological evolutionism Kant, our analysis has shown, never once professed belief in the transformist; nor did he ever show an ability to apprehend clearly either the precise meaning or the force of the considerations which could even then be adduced in favor of that doctrine.

[39] Only by disregarding the natural construction of Kant's language can the sentence about the "third epoch" be interpreted as referring to past time. Wallace (from whose skilful rendering of the passage I have borrowed some phrases) asks: "Has Kant cautiously put the future instead of the past, and hinted at what probably has been rather than what may one day be?" ("Kant," p. 115.) But why should Kant in 1798 have felt obliged to hint so obliquely at an idea familiar to his contemporaries for half a century, which Buffon had hinted at a good deal more plainly, and several celebrated writers had adopted? The desire to avoid theological opprobrium could hardly have been a motive for taking so evasive and misleading a way of imparting his real view. For theological opprobrium was as likely to attach to certain opinions which he frankly accepted—and probably to the hypothesis of the *future* transformation of apes into rational beings—as to the hypothesis of their past transformation.

[40] Goethe's first unequivocally evolutionary utterance seems to be found in his "Vorträge über die . . . allgemeine Einleitung in die vergleichende Anatomie," 1796. Cf. Wasielewski, "Goethe und die Descendenzlehre," p. 27.

UNIVERSITY REFORMS

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AT present there is a wide-spread popular interest in all questions relating to the subject of educational reform, and it may be said with truth of the public, "Thou criest after knowledge and liftest up thy voice for understanding." The discussion is general and not limited to any one locality, nor confined to any particular social class. Over their cups of afternoon tea Mrs. Jones discusses with Mrs. Brown the respective merits of different educational systems, and at the club many an old graduate is up in arms at the mere suggestion that the boys at college are now made to spend too much time over their books! College presidents in their public utterances are decidedly optimistic in regard to the prospective value of this or that proposed change in the curriculum as hastening the day when the colts driven to water will drink eagerly from the fount of knowledge. It is fortunate that the note of optimism has been so loudly sounded by prominent educators, for only those who set out with hope may keep the road across the plain in which lies many a miry "slough of despond."

The task of a university president is no sinecure. The public, which includes many fond parents, is beginning vaguely to realize that something is wrong with our educational system, and as many a boy about to graduate from the university fails to appreciate the value of culture and has no overwhelming love for learning, it is only natural that the parental disappointment should attribute the failure to the last person controlling the throttle of the educational machine, namely the college president. At once the system is blamed, changes are proposed, new hopes are aroused, a general culture is promised, the elective system is dropped, courses are prescribed, the boys are forced to work, and then believing a panacea has been found the public temporarily loses interest in the discussion.

Again the machine grinds on until some one makes the discovery that the majority of the undergraduates do not read "Culture and Anarchy," nor do their copies of the "Novum Organum" show signs of being well-thumbed. The wave of public interest rises again and breaks with such force that the foundations of more than one institution of learning are shaken. The army of the Philistines not having been routed by the frontal attack, strategy is substituted for force, and with the same generals in command a flanking movement is planned. The functions of the brain and nervous system are to be properly adjusted to respond to each and every wave of truth by surrounding the scholars with influences so subtle that unconsciously they are to become inoculated with culture and the love of learning. Experience teaches us, however, that this method of instruction generally produces one of two types of scholars—the savant for vanity "who is quite satisfied with the honor of being regarded as a curiosity himself" or the savant for amusement "who loves to look for knots in knowledge and to untie them, not too energetically, however, lest he lose the spirit of the game." Some of those who in a general way have been the most alert to apprehend the existence of defects in the educational system, without being able to localize the exact seat of the trouble in the machinery, have at times attributed the specific faults to the general tendency to introduce into the curriculum the study of purely utilitarian subjects. This view assumes that useful knowledge is vulgar and has no relation to culture, but fails to recognize the importance of emphasizing, not the subject studied, but the methods of work acquired. While many persons take an active interest in the discussion of the general problems of education, very few seem to appreciate that the acquisition of either culture or learning implies the subjection of the most complicated and delicately balanced organ of the human body, the brain, to a series of protracted tests and strains of considerable intensity. The general attitude of the public to the whole subject of education is very well expressed in the lines of Goethe:

Mein Kind ich habe es klug gemacht
Ich habe nie über das Denken gedacht.

In spite of the growing interest in the subject it is becoming more and more difficult to find an accurate definition of education, because each individual has his own ideals which may be regarded as the product of his past and present environment. We judge of the merits of a given system by the finished product, the individual scholar, and we argue in favor of the humanities, or of the sciences as the case may be, merely because certain types of scholars appeal to our personal predilections. We are apt to attribute the possession of the mental traits of those individuals who by their attainments represent the personification of our ideals to some special system of education (belonging to some school, college or university), quite forgetful of the fact that various subtle influences, such as heredity and environment, have been the most potent factors in determining the final result. An education, even if wisely planned and well directed, adds nothing to the natural brain power of the individual; it merely gives his latent faculties an opportunity to develop to their highest point of efficiency. If we could add one jot to the latent capacity of any scholar's brain there would still be hopes of making the silken purse from the sow's ear.

We find one person the possessor of a certain kind of knowledge and hastily draw the inference that the mere acquisition of a similar store will bring out identical mental traits in other individuals irrespective of their mental capacity. This point of view has unfortunately given rise to an excessive faith in the special potency of certain kinds of knowledge, and has engendered a sentimental belief in the educational value of first one and then another subject. As a matter of fact, experiences teach us there is only one kind of knowledge and one way of acquiring it. The general tendency of educators to prescribe definite mental tasks in order to increase the efficiency of an organ whose functions they have never seriously studied is analogous to the practise of the physicians of the old school with their inordinate faith in the specific power of a large number of drugs to cure diseases. There is no reason for supposing that a professor of Greek or chemistry should be more capable of estimating the capacity of an individual student's brain than there was for the barbers in the reign of Henry the Eighth assuming that they possessed sufficient knowledge of the anatomy of the human body to entitle them to perform the duties of general surgeons.

No matter how much intelligent persons may differ in their expressions of belief as to the relative merits of educational systems, there is a general agreement as to the nature of the distinctive differences between past and present systems; the former laying stress upon the character of the information gained, the latter emphasizing the importance of the mental habits acquired. The results aimed at by modern education have been well defined by Ex-President Eliot as "an initiation of mental processes and the establishment of good mental habits, with incidental acquisition of information"; and according to President Lowell "the essence of a liberal education consists in an attitude of mind." From this it may be seen that the importance of good mental habits or, if we choose to express the same idea physiologically, of a well-balanced brain is an essential factor in the pursuit of culture; for although we may get to know the best which has been thought and said in the world, we must still have the power "to turn a stream of fresh and free thought upon our stock notions and habits." If we start out from this physiological point of departure the absurdity and irrelevancy of much of the talk at the present time as to what should and should not be taught in the universities is apparent. When an individual has acquired bad habits of eating, bolts his food and develops symptoms of acute indigestion, he is not generally advised to eat more, but is told to learn how to chew and to eat less. Most of the boys who enter the universities have suffered from one or more attacks of mental dyspepsia; through no fault of their own they have acquired bad mental habits, and nature has made an attempt to readjust their mental balance by giving them a distaste for more food. But, in order to sell the stocks in the educational shop, still more food is prescribed. The bad mental habits become worse and the only redeeming feature is that, in the attempt to get a general culture, so many different kind of pills are prescribed that the fatal dose of any one is never administered.

When the mental balance of an individual becomes so distorted that the currents of thought always run in certain grooves, from which they never emerge and there seems to be no hope of readjustment, such a person is said to be the subject of "fixed ideas" and then the educator is only too anxious to disclaim all responsibility in the patient and shift it to the alienist. In view of the fact that more and more emphasis is being placed by prominent authorities on educational subjects upon the necessity of insisting upon the importance of the formation of good mental habits, we may ask whether any well-organized effort is being made by the universities to determine the conditions upon which the greatest efficiency of brain activity depends; and then to use this knowledge to arouse and train the potential mental capacity of the students, so as to produce men with sound minds and sound bodies.

When we approach the discussion of our subject from this standpoint, it is quite obvious that the first and most important questions to be asked relate to the methods to be adopted in training the brain; and second, and quite incidental, to the character of the information to be imparted. It is the first of these two subjects that we shall concern ourselves at present. No matter how much we may differ as to the value of educational ideals, all are pretty well agreed that there are certain definite readily recognized qualities of mind possessed by the educated person. First, there is general intelligence with a marked degree of associative memory, a certain poise or balance commonly designated as good judgment and a tentative rather than a fixed attitude towards knowledge, a capacity for concentrating the attention, a quota of emotional activity well under control and a dominant will. Science has taught us that these mental traits are an expression of the functions of the nervous system, and in order to understand them properly, they should be studied as the quantitative and qualitative measure of the individual capacity of the brain. No intelligent person to-day questions the fact that the more marked anomalies of cerebral function, as seen in idiocy, imbecility and the various forms of psychoses, can be analyzed and correctly interpreted only by those who have had the requisite special training and experience in connection with the study of the brain. With a singular disregard for logic and common sense, many intelligent persons assume that special skill and experience is not necessary in order to analyze the subtler and less defined anomalies of conduct as revealed in the daily life of normal individuals; nor is any intimate knowledge of the structure and functions of the brain considered essential to those whose duty it is to bring this organ to its highest state of efficiency.

For various reasons, which it is not necessary to recapitulate, investigators interested in the study of the functions of the brain have at all times found themselves more or less in conflict with many of the accepted philosophical theories that served to obscure the issues and make progress difficult. King Frederick William's antagonism to the new ideas introduced by science into the study of psychology is a historic example of the difficulties which popular prejudice has created. This sovereign's refusal to believe in the application of the law of cause and effect to the study of mental phenomena, because he would thus be deprived of logical reasons for punishing the deserters from his Grenadier Guards, finds many analogies even at the present day.

All forms of conduct in the higher as well as the lower organisms are an expression and measure of the functional capacity of the nervous system. From the protozoa to man we can follow the constantly increasing complexity of function as revealed to us in behavior without being able to pick out a single trait as specifically characteristic of any particular organism. Herrick has called attention in a very interesting way to the fact that animals widely separated from each other in the scale of functional and structural complexity, as the annelid worms and the vertebrates, present striking differences in behavior referable to the contrasted types of nervous system represented in these two groups. The behavior of the former, stereotyped and predetermined, may be inferred from the structure just as the "plastic individual reactions of the intelligent type" are dependent upon special arrangement of the nervous mechanism of the latter. Between these two extremes are countless gradations in conduct as well as in the arrangement of the nervous system. The prevailing ignorance in regard to facts of the most elementary character relating to the structure and functions of the nervous system is well illustrated by the remarks of an English acquaintance, a graduate of Oxford and a recognized ecclesiastical authority upon matters of conduct, who when told, in reply to an inquiry, that fish had brains, after a brief period of meditation replied, "Really, that's quite an idea." What a strange comment upon our present methods of education that an individual altogether ignorant of the structural and functional capacity of the brain of a fish, which differs from the human brain only in the simpler arrangement of its elements and the greater limitation of its functions, should be considered an authority upon the training of the most complicated nervous system in the whole animal series!

The dawn of consciousness, the simplest form of memory, the element of choice in volitional acts, appear far down in the scale of living creatures, and this law of recapitulation in the behavior of organisms is repeated step for step in the life history of each individual. From the first movements of the embryo until the adult has reached the prime of development, the line of progressive functional development is unbroken. In the earlier studies made upon the brain local lesions such as those caused by apoplexy, injury, tumors, etc., were the first to attract and interest the public as well as physicians. It was much more difficult to understand the diseases of the brain not dependent upon localizable lesions, but gradually a way was found leading to a better understanding and clearer analysis of the mental disturbances occurring without discoverable lesions. But the brain is so complicated an organ that a slight interference with its mechanism may give rise to complicated functional disorders involving the entire personality. As a matter of fact comparatively little is yet known in regard to the cumulative effect of disturbances in the mental activity incident to relatively small lesions in the higher brain centers. In the study of the various psychoses the alienist has found a complete analogy to the results obtained in the study of the comparative physiology of the brain. When the attempt was made to analyze the anomalies of conduct in the insane it became evident that no distinctive qualitative difference separated them in behavior from normal individuals. In the daily ups and downs of the ordinary life are found the basis of the pathological conditions known as manic-depressive insanity, while in the precocious bizarre habits of young people and children are recognized the germs of that sad group of cases known as dementia præcox. In the rigid inflexible opinions so frequently expressed in the discussion of religious or political questions we find the key explaining the stand-pat positions of individuals subject to chronic systematized insane ideas.

The individuals showing a particular bias, or those inoculated with the spirit of excessive partisanship, the sentimentalists, the whole host of faddists, the doctrinaires, the obstinate and the bigots to a certain extent reflect but to a less degree some of the mental traits of the paranoiac. The permanence and intensity given to certain ideas have been the result of the emotional storms attending their appearance in consciousness, and in the latter condition, where a marked psychosis has intervened, the intense emotional reaction has subsided and the idea has crystallized out of its setting. In the normal individual when one function of the brain is nicely balanced against the other the analysis of behavior is, as a rule, more difficult than it is in the insane in whom the exaggeration of different traits of character becomes so marked that a clue as to their origin and development is given.

In the history of psychology it is particularly interesting to note that practically every advance made in this department has followed close upon the incorporation of the conceptions and terms of natural science; and it is equally obvious that the delays and regressions have been due to that general tendency to give up the study of particulars, and as Bacon puts it, "to view nature as from an eminence." It was this tendency which induced Kant, after having started in the right direction, to affirm that the development of man's moral and intellectual nature lies beyond the problems of natural science.

Sufficient has been said to emphasize the great importance of the study of the brain and nervous system as the only effective way of establishing a more rational system of education. The most important consideration in the whole field of education is not the discussion of methods for conferring the present opportunities indiscriminately, so that all may avail themselves of them, but rather to determine how the educational system may be modified to meet the needs of each individual. Gradually the public is beginning to awaken to the fact that a so-called higher education may not only fail to act as a panacea for all human ills, but may become a potent factor in increasing the mental and physical degeneration of the race. An overtaxed brain and nervous system may not only be followed by a nervous breakdown, but it may expose its possessor to temptations which seriously interfere with his morality. It will be a fortunate day for the community when it appreciates that a sound morality depends not so much upon an individual obeying the dictates of philosopher or priest as in following out the injunctions of the physician.

So far as I am aware, Dr. Adolf Meyer was the first to offer the suggestion that departments of mental hygiene should be established in all our universities where advice could be given to teacher and student upon questions relating to the training of the brain and nervous system to the limit of the individual capacity as estimated by competent persons, so that these limits should not be exceeded. In this way it would become possible to gradually train teachers who would be competent to form a correct judgment as to the quality of each student's mind and the futility of attempting to estimate the mental capacity by the amount of information acquired would be more generally recognized. The present system of tests generally represented by written examinations is an incentive to encourage memorizing, but is a serious obstacle to logical thinking. The mechanical memory is frequently an evidence not of intelligence, but of certain forms of imbecility. An examination conducted along the lines suggested leading to a qualitative estimate of a particular student's mental capacity would not be a difficult task for those who have had the proper training. Any intelligent physician skilled in the methods of modern psychiatry could in a comparatively short time form a relatively accurate conception of the qualitative character of the mental processes of an individual under observation. Frequently common sense alone, but more often when combined with a desire to profit by the financial aid given by life-insurance companies, is a potent factor in inducing individuals to seek medical advice in regard to the care of the heart, lungs and other parts of the body; but one organ, the most delicate of all, the brain, is sadly neglected, until some already well developed disease has compelled the patient to seek the advice of the specialist. In our schools and colleges considerable attention is now being given to the prevention of those having weak hearts or lungs from taking part in athletic contests, whereas at the same time practically no attempt is made to discourage those with functionally impaired nervous systems from undergoing the excessive tests imposed upon them by the strain of a modern education. On the contrary, every attempt is being made to induce all, the unfit as well as the fit, to pass through the educational mill. Those who fail become objects of pity, even if they keep out of the police courts and do not end their careers by suicide.[1] If the latter event terminates their career, those concerned in the general carrying into effect of the campaign of an education, which has given rise to such remote but undesirable consequences, are not even indirectly blamed, whereas the individual's memory is frequently anathematized by ecclesiastical authority and his or her mortal remains are refused burial in consecrated ground. The public's indifference to the importance of this general question of the introduction of a more rational system of education is commended by Mrs. Grundy. If it were not for the influence of this lady it would be possible to subject each student during his college or university days to an examination to determine whether his sense perceptions were below normal, his memory defective, his power of the association of ideas impaired and his volitional control diminished, with the object of giving intelligent advice to correct, if possible, the deficiencies, thereby increasing the individual's sphere of usefulness, and in many cases averting by these precautionary measures a complete breakdown.

One of the reasons why educational psychology has not fulfilled the predictions made for it by its most enthusiastic supporters, may be referred to its failure to recognize the value of a principle of fundamental importance which directs our attention to the necessity of the study of the brain in its relation to other organs. The idea of the possibility of isolating and studying the functions of the brain analytically quite apart from the phenomena occurring antecedent to the appearance of ideas in consciousness, and conditioned by the activity of heart, lungs, liver and other organs, is an unfortunate persistence of that form of the dualistic conception of the relation of mind and body which has so long delayed enquiry in this field. Though it is always dangerous in the development of any new department to awaken public interest by promising immediate results of importance, a good deal of information of practical value could be disseminated which would tend

[1] In the year 1908 there were some 8,332 deaths from suicide in the United States.

toward the reorganization of the curriculum in our higher institutions of learning. The number and grouping of subjects in the different courses of study now generally followed in most of our schools and colleges represent the selection brought about by the natural development of an educational system in which the chief aim has been to impart information rather than to supply the means for bringing the functional capacity of each individual brain to its greatest efficiency. To those who have had experience in studying the mental phenomena of individuals, it is apparent that the great number of subjects now crowded into university courses, can only result in giving many of the students mental indigestion. This is one of the reasons why so many young men leave college or the university without, apparently at least, having gained any real intellectual pleasure from the work which they have undertaken. There is an apparent indifference to higher ideals, while the feeling of pleasure which should be associated with normal mental activity is quite lacking, as a result of the surfeiting during the school and college days. The constant effort made by the student to readjust his mental focus upon first one and then another subject dissipates energy, destroys initiative and gives rise to a certain ennui which is one of the first symptoms of fatigue.

The apparent but not real lack of originality in American students, and their inability to work out problems which require long-continued effort in one direction are referable not to any inefficiency on the part of the student, but are the result of the system of education to which they have unfortunately been subjected and that is quite lacking in discipline. The physiologist early appreciates that under the present curriculum of study in our universities so many subjects are introduced that it is only possible for an individual to acquire information in regard to the great variety of topics, but no time remains for him to be drilled in the mental discipline essential to the formation of good mental habits. Few students are ever given time, even if they have the inclination, to follow Newton's precept of thinking long upon one subject or to imitate Darwin's example of keeping a subject in mind for a number of years without ever losing sight of it. Modern education is undoubtedly defective in depriving the student of the time and the incentive to prolonged meditation, an absolute essential to great achievement.

In connection with the work of the department referred to, advice could be given in individual cases with the view of correcting functional disturbances of the mental activities, such as inattention, anomalies of the will, and other impediments to education.

The important part played by slight physical deformities in the development of the personality was clearly shown by a French throat specialist, who years ago made the interesting observation that whenever there was any obstruction to the drawing in of air through the nasal passages it was extremely difficult for the individual, thus afflicted, to focus his attention for any considerable length of time upon any one subject. Since the days of Krishaber, great numbers of other physical causes have been found which, if not removed, may greatly impair the dynamic power of the attention even if the cause is slight. The general irritability and fretfulness of children with defective vision or enlarged tonsils, the malaise and apparent laziness so frequently a symptom of anæmia or neurasthenic states, the emotional outbreaks of temper, the destructiveness, the grimacing and the tics of St. Vitus' dance, the abnormal imagination, the tendency to lying, precocity and self-centeredness in hysteria, are symptoms which, if exaggerated, should be regarded as signs of immediate danger to the individual, but even when less pronounced they often become the danger signals indicating a serious but slow degeneration in the mental and moral development of the child. The important point to be born in mind in this connection is that an almost inappreciable defect in the mental activity of an individual, if persistent for a long period of years, may ultimately result in profound changes of the entire personality. This is not only true in regard to defects in capacity for attention, but is equally true in regard to the still more important functions of feeling and will. As an example we may cite the popular conception, to which expression is so frequently given, that a young man should not work too hard during his university days. This notion takes no cognizance of the fact that the sloppy mental processes following a protracted period of mental inactivity make it impossible later for the individual to direct his own thoughts. One of the chief lessons taught by modern psychiatry is that the persons the most subject to mental disturbances are those who early in life have failed to form good mental habits. Individuals do not break down as the result of hard work, but failure comes from the inability to adapt their mental processes to the new conditions in which they have frequently been cast and by the sudden strain put upon the brain whose functions have deteriorated through inactivity. The attempt of the indolent to find an intellectual justification for their sins of omission is in direct opposition to the doctrines of physiology, which teach us that the strength of any organ is increased by the proper exercise of its functions. This is a lesson which should be taught to students in our universities, and a few hints should at the same time be given as to the methods of work to be adopted, after which the students should be encouraged to go forward themselves.

The importance of emphasizing the cultivation of a healthy initiative in thought, as well as action, is a subject upon which there is apparently little opportunity for disagreement among intelligent persons; and yet many forces operating at present are antagonistic to the development in students of this important mental trait. There is a very specious form of individualism which is frequently mistaken for independence and originality in thinking. The former is characterized by lawlessness and an assumed disregard for the ordinary laws of thought and conduct. In the events of ordinary life such fools rush in where angels fear to tread, whereas the initiative developed by a sane and effective process of education is analogous to the strong man's desire to run a race, reasonably conscious of his power to vanquish his competitors. But unfortunately in most of our universities real originality is repressed, or often killed by the curriculum, conventionalities and petty criticism. Students are easily forced into the class of people described by Mill as liking things in crowds. They are seldom compelled to exercise their own senses, and a mass of ready-made judgments upon literary and historical subjects is heaped upon them before they can stand straight, their own ideas being dwarfed and eradicated in order to make room for the borrowed knowledge. It would be as novel as instructive to hear a professor address his students as follows:

> Young Gentlemen, I advise most of you not to attend my course in history, but to substitute for it some form of instruction where you will be compelled to exercise your own eyes. Take a course in drawing, or of nature study, learn to see things, to form your own judgments, and when you have shown your ability to collect data and to form an independent opinion as to the relation and value of particulars, I will then give you my own and the views of others upon historical questions.

Students are very frequently so impressed by their instructors with the importance of imbibing knowledge that they fail to scrutinize the information given them and thus readily lapse into a condition in which no resistance is offered to the forced feeding. And if the process is continued, a positive distaste for knowledge is developed. Leonardo da Vinci clearly recognized this plethoric state of mind, for he admonished his readers that "just as food eaten without appetite is a tedious nourishment, so does study without zeal damage the memory by not assimilating what it absorbs."

Payot in his "Education of the Will" affirms that the more brilliant a professor is and the more he enjoys hearing himself talk and argue, the less desirable does it become to confide young people to him for instruction, for he gives as little aid in assisting them to acquire the art of working or in making true progress in scientific work as one would bring about a gain in muscle and skill in gymnastics by watching the strong man at a circus.

Closely associated with the question of the choice of methods for the development of the individuality and the capacity of adapting the mental focus so as to include more objects within the field of vision is the removal of all influences tending to limit the horizon and to breed those disorders of personality popularly described as narrow-minded-ness, bigotry and the like. It does not take any special knowledge of the study of mental disorders to recognize some of the chief defects in the present system of organization of our universities which tend seriously to upset the mental balance of teachers and students. A hysterical sentimentalism unfortunately associated with the spread of the "college spirit," has become very intolerant of criticism and when placed upon the defensive immediately resents any suggestion of proposed change in a curriculum "which was quite good enough for our fathers." Generally speaking, conservative Princetonians are amused when the incident is mentioned of that loyal son of Harvard who having found his passage taken on the S. S. *Yale* waited over one entire day in New York in order to return to Boston by the S. S. *Harvard*. One has to go to New Haven, Cambridge or Baltimore, however, to find those who appreciate the concealed humor in the speech of the Princeton alumnus who openly advocated making the attempt to keep Princeton ideals uninfluenced by outsiders and the faculty composed of Princeton men! One of the greatest dangers threatening the development of American universities is the tendency shown to sacrifice individual development in the attempt to advance the interests of a single institution. In European universities, particularly those in Germany, Austria, Switzerland and northern Italy, when two candidates are proposed for election to a professorship, the call is generally given to the outsider. This custom supplies an excellent corrective inhibiting the development of those fixed ideas existing in all communities where the teaching authority is the *lex populi*. An excellent estimate may generally be formed of the professional standing of a teacher by the number of "calls" he receives from other institutions.

Unfortunately in faculties where complete harmony exists the dangers of the growth of the spirit of mutual admiration becomes a menace to healthy mental activity. The objectionable spirit of partisanship is frequently more marked in the professional schools (theology, medicine, law) than it is in the academic departments of the universities. Eternal vigilance is the price to be paid for intellectual as well as political liberty. The method generally adopted in a university of electing a board of trustees entirely recruited from its own alumni without any representatives from other institutions is unfortunate, because the members will almost certainly be guided by a sentimental interest in the affairs of a single institution, rather than by an intelligent appreciation of the intellectual needs of the entire country. The effect, even indirectly, upon the teaching and student body of the selection of a board whose members are chosen because they are supposed to represent the spirit of a single college instead of the broader and more general interests of the national life is narrowing.

If we wish to determine the physical conditions essential to the cultivation of the mental plasticity and poise in order the more successfully to combat all tendencies encouraging a blind reliance upon authority and fixed states of mind, we must know something about the manner in which comparatively slight deviations from the normal balance are converted into the stable systematized delusions of the insane. The alienist quickly recognizes the fact that the sentimental tendencies expressed in the uncritical devotion to the maintenance of the ideals of a single college offer a very favorable soil for the development of petty prejudices and provincial ways of thinking, the directions of our thoughts being determined by the presence of ruts, however much we may, sometimes, attempt to explain them away with all the vehemence of stand-patters. American ideals should be substituted for the Harvard, Yale or Princeton ideals, if we wish to cultivate the quick and ready discernment of the right wherever it is to be found. One of the principal lessons to be forced home upon students, striving to acquire a normal physiological habit of thinking, is to impress them with the fallibility and not the infallibility of individual judgments, but when young men are encouraged to believe that the institution from which they graduate represents *the* most advanced position on the road to the intellectual Mecca, they unconsciously get a mental twist, the effects of which it is difficult to counteract.

The principles of logic and of criticism may be taught in theory, but the conditions essential to the proper selection of premises and the formation of sound judgments are still far from favorable, and this will continue as long as American students are encouraged to form general opinions altogether lacking in discrimination as to the respective merits of different institutions. The same narrowness of vision and absence of charity which have created the barriers of opinion between many of the different theological schools have unfortunately afflicted the universities. When Harvard professors begin to urge some of their students to take a year at Cornell or Columbia, in order to get into another atmosphere, or the benefit of a change to the Cambridge environment is recommended to correct the inflexible mental traits acquired on New Jersey soil, there will be reason to believe that the universities are becoming centers, whence sound advice is being disseminated as to the methods of developing sane and logical thinking. There is danger that the odium institutionum may in a measure replace the odium theologicum of earlier days. Students are often advised to take a trip abroad following graduation in order to readjust their mental foci. The blind devotion to the maintenance of a proper college spirit forbids the entertainment of a recommendation that an excellent prophylactic measure directed against the possible development of this form of institutional myopia would be a year, preferably the senior year, spent at some other American institution.

At present there is only a very vague realization even among those who call themselves teachers that the first duty in imparting instruction is to give pupils some idea of the proper methods of study. McMurry in the preface to his excellent book "How to Study and Teaching how to Study" confesses that for many years he has made this subject his hobby and adds that, after careful search, he has only been able to find two books in English and none in German on the "Art of Study." Few instructors ever give any serious attention to the development of a normal thought-mechanism in their students. Information is imparted together with a great many bad mental habits and the store of knowledge acquired is considered to be the test of the individual's mental capacity. So firmly rooted in our mind is the idea that the amount of information and not the acquisition of good mental habits is the chief end of an education, that we fail to recognize the dependence of our thoughts and actions upon the reactions of the nervous system. The tentative attitude of one person and the ready acceptance by another of articles of belief are conditions created by the responses of the nervous system to the needs of the individual. The mental traits, functional expressions of the capacity of the nervous system that make it easy for one person to believe, may in another tend to the development of an habit of mind which makes it difficult for the believer to realize that, even in matters of belief, no one is altogether right.

According to Professor William James old fogeyism begins at an earlier age than the majority of persons believe to be the case. The symptoms may appear at twenty-five. In spite of the general existence of this presenile form of deterioration, we still clamor about the necessity of a broader and more general culture, as if it were possible to correct one bad habit by substituting others. Much good would undoubtedly be accomplished by the application of the methods of modern clinical psychiatry to the study of the sources of the prejudices and various forms of intellectual intolerance which have resulted in the painfully slow progress of the human race. In the examination of patients in the clinic, a careful study of their powers of sense-perception is conducted before proceeding to an estimation of the capacity for originating and associating ideas, or for forming intellectual judgments. Our universities sanction the perversion of the normal mental activities of students by encouraging them to debate, to have a ready opinion upon many subjects, and to talk glibly in public, before they have shown any capacity to gather the data presented to consciousness by the medium of the sensory tracts (touch, taste, smell, sight, hearing) and to arrange and compare them so as to form independent judgments. Rosen in an interesting book[2] has shown us that the greatness of the old masters was due to the acuteness and accuracy of their

[2] "Die Natur in der Kunst," Leipzig, B. G. Teubner, 1903.

perceptive faculties. They were able to paint as no modern artist can, because they studied nature closely and were seldom blinded or deafened by the critics. The ennui often appearing in a student following a course of didactic lectures is the result of the forced rumination upon the very few facts which he has been given opportunity to acquire through his own efforts. Modern education is still defective in training the sense-perceptions and the continuous meditation upon the few data furnished us by our own eyes and ears produces a state of mental fatigue, so that finally the tendency to reiteration becomes as annoying as the constant effort to count the figures on the wall-paper to the fever patient, or as the blind impulse compelling the child with St. Vitus' dance to touch each telegraph pole, as he walks near it. Even if we admit the truth of the dictum that there is nothing in the intellect which was not first in the senses, we are not guided by this idea in arranging courses of study. Boys are still forcibly carried through their school and college days in the same spirit in which personally conducted parties are rushed through the Vatican galleries. As the result of the so-called liberal education, the student frequently finds that he has actually become deficient in his sense perceptions and has acquired a faulty thought-mechanism; although possibly he finds some consolation in feeling that conventionalities have been satisfied by the completion of the grand educational tour. But sometimes, when it is too late, here and there one begins to appreciate that he has eyes and can not see, ears and can not hear.

Closely associated with the ideational faculties are the phenomena collectively designated as Will. The careful study of individuals, somewhat as practised by the skilled alienist, has taught us that a great deal may be accomplished in the training of the volitional powers. The old method employed to strengthen the will was similar in many respects to the practise indulged in of teaching children how to swim by throwing them into deep water. In a few cases only was the method successful. The remarkable advances in the study of the comparative physiology of the nervous system combined with the careful analysis of the conduct of individuals made by psychologists and alienists have shown conclusively that all our volitional acts are the expression of the activities of the brain.

The old axiom predicating the existence of free will is a pure fiction. When we speak of the will custom and usage have unfortunately led us to suppose that the volitional act is a phenomenon quite unrelated to other events in our mental life. As a matter of fact, the will-act is a very complex affair, depending upon a variety of conditions. Here is an example: It is a pleasant summer-day and as I sit at my desk and write, two conflicting impulses shoot up into my field of consciousness. One tendency is strong to get up, leave my work unfinished and take a walk in the country. The other keeps me at my desk and busy with my writing. Each impulse is the resultant of a complex of sensations, ideas, habits so involved and intricate that in the present state of our knowledge only a superficial analysis is possible; and what I shall will to do in this particular case is largely the resultant of a series of acts that have gone before. Abnormal mental states emphasize certain components in the mental chain, so that we can get an inkling of the mechanism involved in the expression of volitional choice between two motives. If it is blue Monday and I am mentally depressed, the tendency to sit still at my desk and mope is stronger than either of the other two motives, and if the depression deepens, every effort becomes difficult, the sense of the freedom of the will is reduced to the minimum, and it may be that the normal desire for food vanishes. Finally in an extreme case physicians and nurses are brought in to force the feeding and give the general treatment necessary to restore my lost energies and key me up to the pitch when simple decisions are no longer associated with an abnormal sense of effort.

Another condition may occur, and instead of being depressed, I am exhilarated. The sense of effort is diminished, action becomes easy and the sense of fatigue is absent. Impulses to action, to walk, talk, write, gesticulate, are constant. During the period of depression, I was on the earth, now I am walking on the clouds. Ideation is rapid. I dash off sentence after sentence, or I walk miles with but slight sense of fatigue. The obstacles to effort created during my period of depression vanish into thin air. A whole host of sensations of a pleasant nature stream into my consciousness and the passage from the depths of Lethe to the heights of Olympus is completed. If the depression or exhilaration surpasses certain bounds established for convenience sake by legal authorities, the analysis of motives becomes easier than in the instances where the rises and falls in the emotional life are less marked.

There is a very promising field for prophylaxis in preventing the occurrence of abnormalities in the volitional acts. One or two examples will suffice to indicate our meaning and suggest the corrections. Many of the beneficial results of athletic sports are almost entirely lost by the encouragement given to the hysterical manifestations of emotionalism, which so frequently affect the spectators even more than the participants.

The lack of practical interest in a preventive morality is shown by the university authorities who permit the members of a football team to be fed on an almost exclusive meat diet, subjected to the nervous strain of exciting games, and then when the balance of the nervous system has been suddenly upset, expect them to successfully resist the cravings created by the general system of dieting and training to which they have been subjected. When the Roman Catholic church wishes the spiritual to preeminently dominate the carnal impulses, it becomes sufficiently materialistic in practise to advise the believer to fast or at least to substitute fish for meat in his dietary. The individual who has not learned to regulate his diet to his physical and spiritual needs and has not acquired the habit of chewing his food thoroughly, has failed to pass his elementary examination in the field of applied ethics. The physical, mental and moral deterioration beginning in the second or third generation of families which have suddenly acquired wealth may be attributed primarily to the luxurious diet no less than to the other extravagant ways of living.

Still another line of argument in favor of the universities paying more attention to the study of the brain is supplied by the mal-adjustment of great numbers of persons to the unsuitable environment into which they have been driven by the impulses and ambitions awakened by an education ill-adapted to their individual brain capacity. Public charities, missions, settlement work, are all agencies tending to alleviate some of the sufferings of mankind, but we seek in vain for the signs of any organized effort to prevent the perversion of the mental activities of great numbers of individuals which has come about from lack of proper advice and instruction in regard to the selection of an education which will not disturb the balance of the nervous system and generate undesirable impulses, exceeding the inhibitory capacity of the individual.

The number of those suffering from mental disorders is appalling. In Great Britain there are nearly 70,000 idiots, over 47,000 lunatics, 23,000 criminals, nearly 10,000 deaf and dumb from childhood, 60,000 prostitutes, 62,000 epileptics, more than 88,000 backward children and 18,000 habitual vagrants, and many of these degenerates are engaged in breeding offspring! In institutions in the United States we have more than 145,000 individuals in well-advanced stages of alienation and over 120,000 feeble-minded persons, and it is safe to assume that if all the patients suffering from psychoses were actually brought under observation, these figures would be greatly increased. The present cost to the country of partially providing for the maintenance of this army of incapables is well over $40,000,000 a year.

One of the most important functions connected with the work of a department of mental hygiene would be the encouragement given to the investigation of all questions connected with the anatomy and physiology of the nervous system, along the lines where these studies could not be prosecuted to a greater advantage in the laboratories and clinics of our medical schools. Not only in this, but in all other departments the selection of directors from among those who have shown themselves capable of carrying on original investigations should be insisted upon. Only when this spirit has permeated the whole department, from the top to the bottom, is it possible to retain the freshness and mental vigor as essential to the teacher as it is to the investigator. The public, as a rule, does not appreciate the fact that successful teaching and investigating can not be disassociated in the university. The teacher who fails to take an active interest in research is generally deficient in his appreciation of the importance and difficulty of keeping the mind free from all those prejudices which tend to warp both sympathies and judgments and prevent the student from acquiring the faculty of appreciative discernment of new truths. A sharp and purely arbitrary distinction is often drawn between teaching and research, as if the two departments had nothing in common. Many persons look upon the latter as a luxury, something for which provision should be made only after every effort has been expended in teaching students how to meet the conventional restrictions imposed by examinations. The fact that this action is pretty generally accepted furnishes another instance of the relatively higher educational value placed by the general public upon the mere storing up of information than upon any effort made to develop other than the acquisitive functions of the brain. One of the chief aims of a modern education should be to cultivate in the student the spirit of a genuine love for learning. Teachers may preach this doctrine until "crack o' doom" without accomplishing as much by sermonizing as can be gained with the expenditure of less effort in giving practical demonstrations of what it is to learn. The frequent and sometimes noisy arraignments of the mental defects of college graduates made by business men not infrequently contain an element of justification, for many of the former unfortunately give evidence of having been taught to teach without first having been encouraged in their attempts to learn. The teaching not the learning spirit dominates in our American universities. In the selection of a professor the success of a teacher is too generally estimated by the ability to speak well, coin phrases, to give students their mental food in the compressed-tablet form, and in the capacity of maintaining until the end of the course a superficial, even if it be only a temporary, interest in the subject.

In the constant struggle for existence carried on by all nations it has become evident that success will crown the efforts of the people in which the brain power of its citizens has been developed to the highest state of efficiency. Any attempt to confer upon an individual the opportunities of obtaining an education is equivalent to offering him the chance of exercising the functions of the brain along the lines indicated by those who are generally without even an elementary knowledge of a very complicated organ. Rousseau fully appreciated the absurdity of expecting a professional opinion as to the functional capacity of this organ from those having only an amateur's knowledge of its anatomy and physiology, when he suggested that physicians and not philosophers should be considered to be authorities upon educational subjects.

Thinking and behavior are phenomena dependent upon the existence of a brain and nervous system. The greatest advance in our educational system will begin when the universities require that those who assume to speak with the voice of authority upon these two important topics, shall have as thorough a knowledge as can now be obtained of the functions of the organ the development of which has alone placed us on a higher plane than that attained by our remote ancestors, the anthropoid apes. If we are sincere and earnest in our solicitations as to the hastening of the millennium where wisdom and culture shall be a common possession, let us see to it that every opportunity and encouragement is extended by the universities for the study of the methods of developing the delicate mechanism and fine balance of mind expressed in the mental qualities indicative of culture and learning. It is safe to predict that in the near future those universities will be considered the most advanced and those nations the most intelligent where the greatest encouragement is given to the study of the organ on the functional efficiency of which the advance of the human race towards a higher civilization depends. Anatole France has said the periods in which little intelligent interest has been taken in the study of the structure of the human body have corresponded with the ebbs in the advancing tide of civilization. It is no exaggeration to affirm that to-day the measure of our civilization is to be estimated by the effort made to gain a clearer and more comprehensive knowledge of the brain and its functions, with the purpose of maintaining the thinking-power of the race at its point of maximum efficiency.

The first duty of a university, we are told, is to engage in active warfare with ignorance. Over the portals of many an American institution is carved the figure of the eagle as symbolic of the spirit of the attacking forces. In too many instances, however, conditions would be better symbolized by another bird which closes its eyes to its enemies and buries its head in the sands of the deserts.

If the brain is the only organ to be used effectively in the fight against the foul fiend of ignorance, it is not creditable to American universities that they have thus far given so little attention to the proper study of the weapons to be used.

IS THE DIMINISHING BIRTH RATE VOLITIONAL?

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IT is quite generally agreed that the conditions of modern life make for a lower birth rate. But whether they make for voluntary or involuntary sterility, there is much diversity of opinion. Economists quite generally incline to the first of these views while many biologists incline to the second. Now it must be admitted at the outset that there are no statistics by which the merits of this controversy can be definitely settled. We are left, therefore, to ascertain where the probable truth lies in the light of certain considerations of a more or less general character.

I

The biologist maintains that the human organism requires a certain amount of food, clothing and shelter for the normal development of the body and to repair the wear and tear to which the varied activities of life subject it. He maintains, furthermore, that the stress of modern life is such that after other demands have been met there is often insufficient energy left for reproduction. In other words, in a fiercely competitive world the reproductive organs are undernourished until they are incapacitated to perform their special function. In accordance with the conservation of energy mental activity is said to withdraw the blood from other parts of the body with the result that the tissue of the brain is built up at the expense of other organs. The stress to which present-day conditions subject the eye is illustrative. Primitive man uses the sense of sight but sparingly, while civilized man uses it well-nigh incessantly, much of the time by lamplight, either at study, in the factory or office, or at newspaper reading on steam car or trolley until it is overtaxed. The burden thus imposed, so the biologist asserts, makes such a demand upon the fund of human energy as to interfere with the birth rate. Whether one sex is more frequently the victim of the sterilizing process than the other, there is, so far as I am aware, no consensus of opinion.

The biologist sometimes varies the preceding statement of his position by emphasizing the difficult nature of the task imposed upon the reproductive organs. So complicated is the work assigned them that it can only be successfully performed when the involuntary regulatory system is in a highly efficient condition. This regulatory system, we are told in turn, is so delicately balanced that its efficiency is frequently impaired by the furious rate of our business and social life. According to this view, the diminishing birth rate is not due to the under-nutrition of the reproductive organs, but rather to a breakdown in the machinery which normally controls their functioning.

In further support of his position, the biologist rests his case upon an inference. Observing that the higher animals are less prolific than the lower, he concludes that fecundity among the more advanced types of the human race is necessarily smaller than among the less advanced. Or taking his clue from the fact that wild animals when made captive become less fertile, he asserts that the industrial and social changes of the last fifty years have had a similar effect upon the human race.

Finally, the explanation of the biologist is occasionally supplemented by that of the medical expert who emphasizes the amount of involuntary sterility induced by sexual diseases. Modern transportation and the growing density of population, together with the increase of wealth and leisure, are said to spread the taint of sexual disorders by making possible more promiscuous relations between the sexes. The immoral relations which wages insufficient for self-support or for an attractive manner of dress tempt some young women to sustain are now and then mentioned as a contributory factor.

II

While conceding a certain force to the position of the biologist and the medical expert, the economist insists that it offers a far from satisfactory explanation of the phenomenon in question. Doubtless sexual diseases account for a good deal of involuntary sterility. Some authorities hold venereal diseases responsible for fully twenty-five per cent. "of the inability to procreate in man," and for more than fifty per cent. "of enforced sterility in woman, to say nothing of the one-child sterility where the conceptional capacity is absolutely extinguished with the birth of the first child." This leaves us quite in the dark, however, concerning the proportion which sterility that is involuntary is of the sum total of all kinds. More important still, there is little evidence that incapacity due to sexual diseases has become more common. The fact that existing conditions afford greater opportunity for the spread of such diseases no more proves that this has actually occurred than the increase of positions of trust proves the increase of theft. For the achievements of modern civilization are scarcely reconcilable with either the increase of dishonesty or with growing laxity in the sexual relations. Nor do the temptations incident to low wages prove that an increasing proportion of women lead lives that are impure. Certain it is that economic independence was never so consistent with chastity among women as to-day. Moreover, it is not clear that venereal diseases are most common in that portion of the population where the birth rate is lowest. The social evil in its refined as well as in its vulgar forms is nothing new.

The economist further objects to the inference which the biologist makes from the difference in fecundity between the higher and the lower animals, or from the fact that wild animals become less fertile in captivity. The argument from analogy can easily be pushed too far. According to Malthus, the power of reproduction is less among barbarous than among civilized races.[1]

The economist also takes exception to the main contention of the biologist. Without presuming to take issue with the biologist in his own field, one may at least ask whether the decline of the birth rate has not been too sudden and marked to account for mainly in terms of a deficiency in the human organism to meet the demands made upon it. In the evolution of the race it is probable that nothing has become more firmly fixed than the power of reproduction because nothing is more necessary to survival. In fact, the persistence of procreative power is one of its noteworthy characteristics. This is so notorious among many kinds of degenerates as to call for the new science of eugenics. Apparently, the ability of the reproductive organs to take care of themselves in any competitive contest with other demands upon the human system is to be presumed. Hence, the theory that the rapid pace of life has lessened the power of fecundity to anything like the extent that the birth rate has fallen seems improbable.

Certain additional facts lend color to this position. If stress in excess of the ability of the body to appropriate nourishment impoverishes the reproductive organs, why is fecundity among the insufficiently nourished, clad and housed so great? In place of a low birth rate among the poor, quite the reverse is true. Adam Smith's oft-quoted remark that a half-starved Highland woman frequently bears more than twenty children illustrates what is a matter of common observation. On the frontier, also, the strenuous and hard conditions of life have been in no wise inconsistent with large families. Indeed, many writers attribute the diminishing birth rate to over-nutrition rather than to under-nutrition.

Again, why should the activity of the brain rather than the activity of other parts of the body interfere with the normal development and nurture of the generative organs? For what is more conducive to contentment, happiness and health than an alert and active mind. A writer in a recent number of *The American Naturalist* remarks: "An impotence ascribed to psychical causes may rarely occur, but concerning this factor, we have, obviously, little or no exact evidence."[2] In point of fact, such meager statistics as exist upon the subject indicate

[1] Marshall, "Principles of Economics," fifth edition, Vol. I., p. 184.
[2] Dr. Max Morse, "Sterility," Vol. XLIV., October, 1910, p. 624.

that the birth rate among college women who marry is practically the same as among their non-college sisters, cousins and intimate friends. Moreover, if the failure of the involuntary nervous system to work properly is responsible for the diminishing birth rate, why is not the phenomenon localized in place of diffused? Amid the quiet retreats of rural life as well as amid the rush of cities, among skilled mechanics and even among day laborers subjected to comparatively little mental or nervous strain as well as among business men and other brain workers the birth rate has fallen. The phenomenon is far more wide-spread than the explanation offered by the biologist would lead us to expect. The excessive use of the nervous system can neither cause its own undoing, or cause the under-development or atrophy of the generative organs in any considerable portion of the population.

The economist further objects to the explanations of the biologist and of the medical expert on the ground of their complexity. When asked for a bill of particulars, they are at a loss to give any reply that is at once simple and clear. The undernutrition of the reproductive organs plus the failure of the involuntary regulatory machinery to function properly offers a complex rather than a simple explanation. Moreover, the matter is still further complicated by adding the influence of sexual diseases. Besides, the argument from analogy seems a trifle fanciful. An explanation of the difference between the birth rates in France and Germany, in Germany and India, in France and French Canada, or again in the different portions of the population of any given country in terms of the will seems much more simple and clear than in terms of one or all of the several explanations offered as an alternative. The variations in the birth rate due to a scanty or an abundant harvest, or to any of the various forms of adversity and prosperity, are more readily traceable to volitional conduct than to physiological changes.

Finally, the economist objects that the biologist unwarrantedly assumes that the birth rate is determined in a purely mechanical fashion. No provision is made for the action of anything but physical and chemical forces. Elsewhere in human affairs the will guided by intelligence plays an important rôle. In so vital a matter as the birth rate, is it reasonable to absolve it from a due measure of responsibility? For the biologist rules out even a will that acts in a predetermined manner. A man enjoys a certain freedom in selecting an occupation, in spending his money, in imitating the dress of others, and in selecting his friends, but is the victim of fate as to the size of his family. Hope and fear are thus debarred from influencing the will in one of the most important domains of life. Such a view looks upon man as purely a creature of circumstances, utterly powerless to respond in any voluntary way to the forces that buffet him about. The position of the economist seems more in keeping with the general character of human nature. For man is a being with the faculty of rational prevision. No trait of civilized man is more distinctive, or more necessary to every kind of progress. Nor is there any department of life in which the exercise of foresight is more indispensable to well-being than the realm of the birth rate. Hitherto, in the formulation of public policy the attitude of moralists, publicists and statesmen has assumed the position of the economist to be correct. Clearly, he who would prove that the birth rate is in the main determined in a manner different from the results of conduct in general assumes a heavy burden. Professor Marshall says:

> In the animal and vegetable world the growth of numbers is governed by the tendency of individuals to propagate their species on the one hand, and on the other hand by the struggle for life which thins out the young before they arrive at maturity. In the human race alone the conflict of these two opposing forces is complicated by other influences. On the one hand regard for the future induces many individuals to control their natural impulses; sometimes with the purpose of worthily discharging their duties as parents; sometimes, as for instance at Rome under the empire, for mean motives. And, on the other hand, society exercises pressure on the individual by religious, moral and legal sanctions, sometimes with the object of quickening, and sometimes with that of retarding, the growth of population.[8]

III

The economist, however, does not rest his case upon merely discrediting that advanced by others. He is able to adduce evidence of two things, namely, a growing desire to limit the size of the family, and a willingness to take the steps necessary to this end, which go far toward establishing his claim that the will is the influential factor in determining the birth rate. There can be no doubt that a large family in the old sense of the word is no longer desired. The increased outlay necessary to raise a child to the age of self-support, an increase out of all proportion to the increase of incomes, in itself constitutes a good and all-sufficient reason. A much more prolonged and expensive term of training and of apprenticeship has become necessary to enter successfully upon many careers. The expense of producing self-supporting men limits their supply as truly as the expense of producing commodities. Again, the economic reasons which once rendered marriage compulsory for women have lost much of their force. The will of woman has consequently become more influential in determining not only the formation but the admission of new members to the family. The desire for ease and the fear of the birth pangs, the craving for an independent life and the desire to realize other aims inconsistent with marriage and offspring have a greater opportunity than formerly to influence the birth rate. Moreover, the keener competition to which the

[8] Marshall, *op. cit.*, p. 173.

growth of cities subjects an increasing proportion of mankind in most progressive countries may well make men hesitate about assuming the responsibility of the marriage relation. Doubtless, also, the business uncertainties and hardships to which people in cities are especially subject during trade reversals contributes to the same state of mind. Besides, the growing prevalence of democracy arouses ambitions and aspirations which enter into competition with a numerous progeny.

There is also evidence of a willingness to take the steps which these conditions demand. In the first place, marriage is postponed at the expense of the child-bearing period of woman, a fact of first importance in lessening the birth rate. It is later marriage among women rather than among men that lessens the size of the family. The postponement of marriage signifies a small increase in the proportion of women who never marry, and a large increase in the proportion who marry either at the end of the child-bearing period or when the time of greatest fertility is partially or wholly over. Later marriages among women are partly of choice and partly of necessity. So far as they are due to men, for one reason or another, proposing later, they are a matter of necessity. So far as they are due to women electing some other alternative, they are a matter of choice. In the one case the preferences of men, and in the other case the preferences of women, are decisive. In either case, however, the matter is voluntarily determined.

In the second place, steps are taken to limit the size of the family subsequent to marriage. It is not necessary for the economist to stake his case entirely upon an increase of continence, though there is little doubt that it has increased.

> There are vicious measures, not here to be named in detail, which keep down the number of births or increase the number of deaths, mostly prenatal, though the infanticide of earlier times is not extinct. By strength and also by weakness, by virtue and also by vice, is the economic mandate which limits the rate of growth of population carried out.[4]

It is well known that the impediments which occasion involuntary sterility are, to some extent, within the power of medical practitioners to remove. The possibility of the contrary, namely, the "voluntary prevention of conception," is, therefore, an unavoidable inference. That this is more than a possibility appears from the fact that many members of the medical fraternity are approached much more frequently for advice by those who wish to avoid children than by those who wish to have them. This undoubtedly points to the use of "preventives" in numberless instances which escape the notice of physicians. Perhaps the chief difference between the more intelligent and the less intelligent is that the devices employed by the latter are the more crude and harmful. Among the principal causes of the diminishing birth

[4] Clark, "Essentials of Economic Theory," p. 334.

rate mentioned by a man of such extensive medical and statistical experience as Dr. John S. Billings "is the diffusion of information with regard to the subject of generation by means of popular and school treatises on physiology and hygiene, which diffusion began between thirty and forty years ago. Girls of twenty years of age at the present day know much more about anatomy and physiology than did their grandmothers at the same age, and the married women are much better informed as to the means by which the number of children may be limited than were those of thirty years ago."[5]

In a footnote of an article on "The Declining Birth Rate," Professor John B. Phillips says:

> There is certainly developing there (in Germany) the desire to reduce the size of the family. The large number of pamphlets treating of methods of preventing conception which have recently appeared and are offered for sale at the bookstores is an indication of the desire for smaller families. There is no law against the public sale of such literature in Germany. In the window of one large bookstore I counted five such pamphlets conspicuously displayed. The price of most of them was below fifty cents.[6]

Another fact which corroborates the position of the economist merits attention, namely, the birth rate is usually low at the points where we should expect. For example, a low birth rate commonly coheres with a low death rate. This holds not only between the different portions of the population of the same country, but also between the populations of different countries. Where sanitary conditions are good and the knowledge of preventive medicine most widely diffused, where the spirit of caution is most prevalent and the numberless little attentions that economize life are most unstintedly bestowed, both the birth rate and the death rate are low. On the other hand, where the reverse of these conditions obtain, both the birth rate and the death rate are high. Apparently, the same forethought safeguards both. Again, so long as the American people were mainly a nation of frontiersmen, the birth rate was high. For on the frontier the man without a wife was at an economic disadvantage and children much more than repaid for their bringing up by the time they became of age. Under these circumstances early marriages and large families were both dictated by prudence. But with the passing of the frontier and the massing of men in cities where a wife and children are often a handicap, and where the opportunities for employment open to the unmarried woman are especially attractive, the postponement of marriage and the small family become increasingly common. Under existing conditions, the highly emotional who lack self control and who are frequently without property or devoid of ambition usually marry young and have numerous children, while those in whom the deliberative

[5] *Forum*, Vol. 15, 1893, p. 475.

[6] *University of Colorado Studies*, March, 1910, p. 161.

faculty is conspicuous and who are people of substance or are highly ambitious commonly marry late and have few children. In other words, the birth rate is usually low among those in whom prudence is highly developed, and imprudence in the matter of marriage and offspring is frequently but a symptom of imprudence in other directions.

President Hadley says:

> It is true that as society exists at present, high comfort and low birth rate are commonly associated, because comfort is made to depend upon prudence. Let the comfort be made independent of prudence, as in the case of the pauper or criminal, and the birth rate tends to increase rather than diminish. It may not be exactly true, as some Malthusians would have us believe, that the low birth rate is the cause of the comfort, but it is much farther from the truth to assert that the comfort is the cause of the low birth rate. Both are the results of a common cause—the exercise of prudence, which gives high comfort and low birth rate to those who are capable of practising it, while those who are incapable of so doing have at once a higher birth rate and a lower level of comfort.[7]

IV

We recur, then, to the question propounded at the beginning, namely, is the diminishing birth rate for the most part voluntary or is it involuntary? The contention that the increasing stress of life causes sterility by impoverishing the reproductive organs, or by disturbing the involuntary regulatory system, while plausible, is open to doubt in so many respects that it is not entitled to great weight. As an explanation it is clearly inadequate. It does not account for the widespread character of the fall in the birth rate, nor does it make due allowance for the various considerations that postpone marriage and render a small family, or no family at all, desirable. Moreover, the argument from analogy is so speculative that not much need be conceded on that score. Unfortunately, the sterility due to sexual diseases can not be so easily dismissed. Even some sociologists are disposed to attribute no small part of the decreasing birth rate among the negroes to this cause, on the ground that "emancipation removed the strong economic motive of the master class to keep their slaves in good physical condition." This explanation, however, does not apply to whites. No one of course who pretends to be informed denies that venereal diseases are a fruitful cause of sterility. But when we are asked to believe that they have spread enough to account for the fall in the birth rate, we may well ask for the facts in the case. Such a supposition runs counter to progress in so many directions and to what seems to be a marked increase in the moral sensitiveness of the race. The opinion sometimes expressed that a majority of men contract venereal diseases prior to marriage may be an unwarranted generalization. The error of arguing the increase of these diseases from their known

[7] "Economics," p. 48.

prevalence in the present is also a pitfall into which it is easy to fall. Professor Willcox well says:

> It is so easy and so fallacious to argue the increase of any phenomena from the increase in the known instances. I am still unconvinced that there is any increase of insanity in the United States and my attitude is much the same regarding the diseases affecting the birth rate. At the same time I admit that the balance of expert testimony is strongly in favor of both these positions.

A final objection to the explanations offered by the biologist and the medical expert is that incapacity is to some extent a by-product of certain kinds of "preventives" that sterilize the reproductive organs. This explains why some newly wedded couples who make it a point to avoid children subsequently find that they can not have them. Of the incapacity originating outside of wedlock, also, some is undoubtedly traceable to this cause. An increase of involuntary sterility, therefore, may be merely a symptom of the increase of the voluntary variety.

The explanation of the economist, on the other hand, has the advantage of simplicity and clearness. To most minds, also, it seems less speculative than do its rivals. Besides, it comes nearer explaining the more obvious and important facts. It squares with the fact that the fall in the birth rate is not confined to any one class, and with the tendency of social phenomena, especially in a democracy, to spread throughout the rank and file of society. Moreover, a point of view that takes the will into account and does not reduce man to a mere automaton is more in harmony with the commonly accepted method of explaining social phenomena in general. The sensitiveness of the birth rate to social and economic changes is admitted by both parties to the controversy. But here the agreement ends. On the one hand, the blind response of the human organism to the environment is maintained. On the other hand, the rational response of intelligence is asserted. One emphasizes the resemblance between man and the vegetable and the animal kingdoms. The other differentiates man from other animate beings. The latter has the decided merit of recognizing what is distinctive in human nature.

Finally, the position of the economist is in keeping with certain patent and well recognized truths. One is that men act with a sense of responsibility in contracting the family relation. The general acceptance of the view that children are invited and not sent undoubtedly makes powerfully for self-restraint and social decency. The general acceptance of the contrary view would undoubtedly increase the birth rate. A second truth, and one consistent with the foregoing, is that the birth rate is well inside the physiological limit. Moreover, it is farther inside than formerly. The evidence is conclusive. First, in most countries all births, save only a small residue, occur within wedlock. Second, women marry later than formerly. This is a fact of tremendous import. The much smaller proportion of women married in the age classes 15 to 20 and 20 to 25 in England than in India largely accounts for the difference between the birth rates in the two countries. Third, in one way and another the birth rate is to an increasing extent consciously controlled in every progressive country. Fourth, early marriages and large families have become less consistent with prudence. The expense necessary to rear children to the age of self-support has become more burdensome. Besides, the rise of other ambitions in life render both sexes more cautious about assuming the marriage relation. No theory that leaves prudential considerations out of the account can possibly explain the manner in which the social and economic changes of recent years have influenced the birth rate. Our conclusion, therefore, is that the diminishing birth rate is primarily volitional, and that the various factors which make for involuntary sterility are of minor importance.[8]

It is of interest to note that so well known a biologist as Professor H. W. Conn, of Wesleyan University, subscribes to this conclusion. He writes as follows:

> . . . I am very glad to give my opinion on this matter, recognizing that one man's opinion on this subject is of no special value except as one vote. My own opinion is that the primary reason for the diminishing birth rate is the voluntary one. The increasing demand for luxury raises the marriage age, and the same desire, together with others kindred to it, lead to the intentional and voluntary limiting the size of families. My own belief, judging from such knowledge as would come to a single individual, is that this is the greatest factor in the diminishing size of families. Indeed, I should rather be inclined to believe that if this factor could be removed we should find the race practically as fertile as in previous generations.

[8] The frequency with which economists discuss the subject of population as compared with biologists deserves a passing notice. Ever since the essay of Malthus there have been few treatises upon economics without a chapter upon the subject. Certainly, any text-book which failed to consider the matter to-day would be regarded as incomplete. A century of criticism has established a fairly consistent and satisfactory body of opinion. Moreover, the periodical literature devoted to economics has in recent years been enriched by numerous articles upon the diminishing birth rate. The American Economic and Sociological Associations have now and then discussed the subject at their annual meetings. On the other hand, there is a scarcity of literature from the biological standpoint. I do not know of any place in print where a biologist has attempted to advance a definite and complete theory of population, and in arriving at the biological explanation of the diminishing birth rate I have been dependent upon stray hints found here and there and especially upon information gained by conversation with two of my colleagues, one a zoologist and the other a botanist. There is no body of doctrine upon population to which biologists subscribe at all comparable to that among economists. In other words, the weight of well-defined opinion supports the view that the decline of the birth rate is volitional.

"RACE SUICIDE" VS. OVERPOPULATION

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ANY conscious restriction in the birth rate is popularly referred to as "race suicide." It is in this sense that Theodore Roosevelt employed the term when he wrote to Mrs. Van Vorst concerning "race suicide, complete or partial." The prevalence of a conscious restriction in the birth rate on the part of the vast majority of American families has been established beyond question, while the facts from which this conclusion is drawn form a basis for the anathema and ridicule which the opponents of a declining birth rate have heaped upon those anti-social individuals convicted of "race suicide." Paradoxical as it may seem, however, these "race murders" are in reality race saviors, for, acting in accord with the dominant evolutionary tendency of modern civilization, they are disregarding quantity and seeking to insure quality.

A continuance of the rate of increase in population which prevailed in the early nineteenth century would have resulted, in the near future of the western world, in an over-population problem as serious as that now confronting China or India. Consider, for example, the problem as it appeared in the United States. In 1800 the population of the United States was doubling itself, by natural increase, every 25 years. Had this ratio of increase continued the native-born population of 1900 would have numbered about 100,000,000, that of A.D. 2000 would have numbered 800,000,000, while the population of A.D. 2100 would have increased to 12,800,000,000 souls, or eight times the entire population of the world in 1900. The argument is thus reduced to the absurd. Such a vast population could not be adequately cared for, and some reduction of the birth rate of 1800 was therefore inevitable.

The reduction undoubtedly took place, for instead of the 100,000,000 descendants of native-born population predicted for 1900, there were but 41,000,000 in existence. The advent of the other 59,000,000 was prevented by a conscious restriction in the birth rate, made inevitable by the abnormal growth of population at the end of the eighteenth and the beginning of the nineteenth centuries.

The reduction in birth rate is clearly shown by a comparison of the United States census figures from decade to decade. From 1790 to 1800, there was little immigration, yet the population of the United States increased 35 per cent.; from 1810 to 1820 the increase was 33 per cent.; 1830 to 1840, 35 per cent.; 1850 to 1860, 35 per cent.; 1870 to 1880, 30 per cent.; and 1890 to 1900, 20 per cent. Between 1890 and 1900 the net immigration to the United States was about 2,000,000.

Deducting this number from the census increase, there remains an increase of only 18 per cent. for the native population.

The figures for England and Wales, a stable country with little immigration, shows even more clearly the abnormal increase of population after 1750. During the 270 years from 1480 to 1750 the population of England and Wales increased from 3,700,000 to 6,500,000, an increase of 2,800,000, or 75 per cent. During the next thirty years, however, from 1750 to 1780, the increase was 3,000,000 or 50 per cent. —an increase for 30 years nearly equal to the entire increase for the previous 270 years.

During the century from 1750 to 1850 the increase was from 6,500,000 to 17,600,000, an increase of 11,100,000 or 170 per cent. In the 270 years preceding 1750 the population of England and Wales increased 2,800,000, or 75 per cent.; in the 100 years following 1750 the population increased 11,100,000, or 170 per cent. The years succeeding 1750 witnessed a remarkable increase in population, an increase considerably below the rate of 1800 for the United States, but far above the rate of England for the three preceding centuries.

The chief influence in restricting the population prior to 1750 was undoubtedly exerted by the enormous death rate, for prior to that period, war, pestilence and famine played havoc with population. It is estimated that from 1618 to 1648 wars cost Germany 6,000,000 lives. The black plague in 1348–49 swept away half of the population of England. The ravages of plague may be imagined by the following death rates for England in plague years.

	Deaths per 1,000 Population
1593	240
1625	310
1636	130
1665	430

When it is remembered that modern science has reduced the death rate in some of the great cities to 15 per thousand, the significance of a death rate of 430 can be imagined. Famine played a less important part in curtailing population than either war or pestilence, but it occasionally became significant.

Any appreciable increase of population before the middle of the eighteenth century was, therefore, prevented by the high death rate, and any increase at all could be brought about only by maintaining a birth rate higher than the phenomenally high death rate. Necessity being then, as now, a kind of stepmother to invention, every device was resorted to for stimulating a higher birth rate. The injunction to "be fruitful and multiply" was accepted as a part of their religious belief and blindly followed by a great portion of the population. Statesmen looked upon prolificness as of near kin to patriotism.

While efforts were being made and effectively made to stimulate the birth rate, equally effective efforts were being directed to the reduction of the death rate. In London the death rate from 1680 to 1728 was 80 per 1,000 of population; in 1905 it was 15; 250 years thus witnessed a decrease of more than 80 per cent. The same fact is shown by the increasing length of life of the population of Geneva, Switzerland.

In the sixteenth century the length of life was	21.2
In the seventeenth " " " " " "	25.7
In the eighteenth " " " " " "	33.6
In the nineteenth " " " " " "	39.7

The gradual checking of the death rate worked a gradual increase in the length of life, and hence, unless the birth rate was proportionately checked, a corresponding increase in the population.

Thus, during the last part of the eighteenth and the early part of the nineteenth centuries, the birth rate (which remained almost unchecked) greatly exceeded the death rate (which was being effectually checked). The result of the great excess of births over deaths is shown in the tremendous increase of population after 1750—an increase which could never have been supported but for the increased production of wealth due to the development of the factory system.

The western world, at the opening of the nineteenth century, presented this significant picture—a high birth rate, a low and decreasing death rate; a phenomenal increase in population made possible by the wealth-producing power of the factory system; and big families treading close on the heels of subsistence. Here was ample justification for the pessimistic gloom of Malthus. Catastrophe seemed inevitable, when democracy entered the field, telling the men at the margin whose families were either unregulated in size or else regulated only by subsistence, that they were free and equal to every other man and had a like right to "rise." The thought was new. "How can I rise?" asked the laborer. "Stop having children," replied the economist. The advice was followed. The family of eight is replaced by the family of two and thus disencumbered of an onerous burden, the laborer is enabled to raise his standard of life.

Until 1750 any great increase in population was prevented by a high death rate. In the succeeding century, as a result of science and sanitation, the death rate was gradually reduced, and an overwhelming increase in population was prevented in only one way—by decreasing the birth rate. The decline in the birth rate therefore saved the modern civilized world from over population and economic disaster.

Conditions from 1750 to 1850 were not in stable equilibrium. The death rate had decreased; the birth rate remained high. Population, supported by the wealth of the factory system, was increasing abnormally. Malthus drew his inferences from these facts, which, if they had remained unchanged would undoubtedly have caused overpopulation. This stage was, however, merely transitory. An equilibrium of population has been reestablished through the saving grace of the decrease in the birth rate, commonly called "race suicide."

THE HEALTH INSTINCT

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"PEOPLE do not take the matter of health seriously." So wrote Professor Bain not over thirty years ago, but in the intervening time how things have changed! If he were writing on the same theme to-day, he would probably say that we take the matter of health too seriously, or, at any rate, that some of us are on the verge of so doing. We have heard of the bicycle face and the automobile countenance, and it would not be surprising if some one should soon describe for us the health-seeker's visage. It may not as yet have established itself as an unmistakable type, but one can already trace signs in a certain worn and anxious expression of countenance suggestive of the approach of starvation, or the fearsomeness of an unseen foe.

In days of old, men sallied boldly forth, fearing naught save the fires of future punishment, and these were likely to be forgotten in the business of the hour. They had too much to do, and too little to eat, to be over-anxious in regard to diet or exercise. But a knight in full armor, or a dozen of them, was as nothing to brave beside the hidden bacterial hosts which now make a constant terror by night and day; while the poison cup was rare and harmless in comparison with "auto-intoxications" and the ravages of "uric acid" with which the dweller in twentieth century time is threatened in the viands he must face each day.

Between the periods of these trying encounters with hidden foes which strike beneath the belt, the seeker after health examines with anxious eye the latest newspapers and magazines for paragraphs and articles which may serve as guides to his sad progress between the ever-threatening Scylla of overeating and the Charybdis of undereating; of exercising too much and of exercising too little. Of leading along these lines he finds no lack, but the teachers are so many and their dogmas so diverse, and the results of following their advice often so disappointing, that the health-seeker's troubles only thicken. Even those whose consciousness has given them no trouble along lines of health are not wholly exempt from the fear, or fear of the fear; for, in many households where the health idea has become rampant, the guest at the board is assailed with advice as to the wholesomeness of this, the hygienic qualities of that, and the proteid content of the other dish, until his own stomach becomes alarmed and cries out even for the flesh pots of the Pharaohs and the jolly admonition to the banqueters to "eat, drink and be merry, for to-morrow ye die."

In the realm of muscular activity the health seeker may be told by the specialist that what he needs is more exercise, and that if he will only take a sufficient amount he will attain unto physiological perfection; while on the editorial pages of one of our dailies he reads that any exercise done in a perfunctory manner is positively harmful. One advises ten-mile walks, and another tells him that walking is the poorest of exercises. On the other hand, there is a numerous company of those who would have us attain the kingdom of health through faith rather than works. Truly, leading in the realm of the physical is as absurdly sectarian and dogmatic as it ever was in spiritual affairs. All can not be wholly right; nor all altogether wrong. Happily there is a Virgil to pilot one through the shades of half-truth expressed by the exercise cult, the chew-long circle, the low-proteid faith, or the Eddyite sisterhood. The guide is an old one—good sense—good animal sense of one's condition for work; in other words, instinct brought up to date.

From the lowest forms of life up, there are but three sets of activities, each depending on the others for its existence and condition —the consciousness of his needs, the ability to supply those needs, and the power to assimilate what has been secured. Life is but a continuous round of these, and there are no more and no less in man; the three functions are a bit more complicated, but they are at bottom the same. Among our animal ancestors each was dependent on himself, and his consciousness never failed to tell him just what and how much food to take, and how much and what kind of exercise he needed, to keep him in best fighting and hunting trim. If this consciousness (instinct) failed him, he went by the board. He took no exhausting walks to add to his energies, he knew better than to get drunk or stuff himself unnecessarily and so render himself a prey to his foes, and he had too much else to do to upset his bodily machinery by morbid introspection. Health magazines are hardly needed by a fox or a bear.

Civilization has brought with it dependence on others, and more time than the average man-animal knows what to do with. The man-child may go on a spree, knowing he will not be devoured piecemeal by his neighbors and that if he gets sick some one will take care of him, and so he goes on a spree, and so he is otherwise careless of his conduct. His instinct for health is blunted and rendered of less use through his dependence and his pleasure-of-the-moment excesses. Appetite, temporary pleasure and laziness, get the upper hand, though the consciousness of what is physically good or bad is still present and can be partially or wholly restored to controlling power. We once heard a young woman who delighted in breaking all the laws of health, remark, after hearing a lecture on the sin of disobedience to such laws, "I do not like to hear those things; they are too true." Her health instinct was keenly alive, but only as an onlooker. Instinct was the first health law-giver, and, modified and brought to date, will always remain the supreme judge in these questions. The present wide-spread interest in things pertaining to diet, exercise, emotional states and other allied subjects, is an awakening of this health conscience, but we are in danger of ignoring the existence of such a guide in the anxious endeavor to follow the many one-sided teachers of the hour.

The three primitive animal functions are dependent upon each other, and so the old, old habit of doing something, of keeping busy, must be a factor, a very important factor, in the health problem. An amœba will travel faster against a current than in still water, and we have known supposed invalids gain strength and flesh under circumstances that directed their energies from thinking about their inner machinery to an outward expression of mental and physical effort of which they would have thought themselves incapable. In those with interests beyond themselves, the instinct for health has a chance to assert itself and to supervise without interference. "The chief good I do my patients," said one who is a physician to the wealthier class, "is to find some occupation for them, some hobby to keep them busy."

The application of the mind-body energies to some fixed object beyond self, arouses and sharpens one's consciousness of physical needs, and, as a result, we know what sort of eating, drinking and exercise make us feel that we are at our best each day.

The same instinctive consciousness will guide the health seeker through the maze of health teaching, and will allow him to appropriate from each doctrine its modicum of truth. If a low proteid diet clears his brain, he will reduce his proteids. If vegetables, rather than meats, bring about more power for work, he will become more or less of a vegetarian. If 3,000 calories seem better for his occupation than 1,500, he will use the former quantity. We wish that instinct could teach him not to recommend what he has found to best suit his own needs, as the best and only thing for all others.

The test, then, of low proteid and high proteid, of few calories and many calories, of an animal or vegetable diet, and of whether we need to walk ten miles a day or to lie on a couch, is the effect these things have in lifting us to our fullest capacity for physical and mental work. The one prime condition for this test is that we be physically and mentally busy as best we may in some useful and unselfish direction.

Where the instinct for health is not sufficient—and with those injured by accident or disease it can not be quite enough—the health seeker should throw the responsibility of choosing what is best for him upon one who has schooled himself for the purpose and who knows, or should know, the body-mind in order, as well as in disorder. He should let the physician do any worrying or serious thinking that is to be done, for now-a-days that is what the physician is for. In the meanwhile he can go forward with life's daily endeavor, content with his physical limitations, and only caring to do his best.

The instinct for health can be cultivated until it is as good a guide as in the lower animals. A semi-conscious instinct, of course it is, but with our growing knowledge of health matters from day to day we can add to it, and so make it fit into our civilized manner of living.

Thinking eternally about health without making health a response to our outward striving, will as surely interfere with, or derange this guide, as the thinking about a telegraph pole will lead the learner on a bicycle to bang into it. If one thinks of the middle of the road, of whether he is up to par in his daily work, the telephone poles of dyspepsia and neurasthenia will take care of themselves; while, if listened to, the health instinct will guide him through the distracting midway of health fads without fretting because he does not find in each show all that is advertised by the barker, or just what is suited to his own particular needs. While strength is a good thing, no amount of exercising will make us all Sandows, and though chewing is important to the process of digestion, no amount of time spent in masticating food will develop in each of us the phenomenal inborn endurance of a Fletcher. It is not "in us," and it is just as well we are not all alike. All that is required of us, and all that we should require of ourselves, is that we develop our innate possibilities until we are conscious that we are at our best, our own best and not another's.

WAR AND MANHOOD[1]

By President DAVID STARR JORDAN

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THE message I shall attempt to-day is a message of peace through the arraignment of war. My attack shall be made from the side of biology, and my text may be found in these words of Sophocles, "War does not of choice destroy bad men, but good men ever."

I shall leave to those who have had far more experience than I, the discussion of the advantages of law, order and arbitration over brute force, which decides nothing. I shall leave to one side all questions of the relations of war to social, ethical and religious development. I shall leave to others all consideration of the horrors of war, its legacies of sin, and suffering, and life-long agony. I shall not consider the costs of wars long since fought, a burden strapped for all time on the backs of the toilers of Europe. I shall not consider the cost of future wars, never to be fought, but provided for in the budget of every nation, again a burden unbearable on those whose chief relation to the life of nations is the burdens nations needlessly impose. I shall not depict the growing strength of the invisible empire of bondholders who are fast becoming the owners of the civilized world, and whose silent nod determines the issue of every great empire in war or peace.

My message concerns solely the relations of war to manhood, as shown in the succession of generations.

Benjamin Franklin once said:

> There is one effect of a standing army which must in time be felt so as to bring about the abolition of the system. A standing army not only diminishes the population of a country, but even the size and breed of the human species. For an army is the flower of the nation. All the most vigorous, stout and well-made men in a kingdom are to be found in the army, and these men, in general, can not marry.

What is true of standing armies is still more true of the armies that fight and fall. Those men who perish are lost to the future of civilization, they and their blood forever. For, as Franklin said again, "Wars are not paid for in war time: the bill comes later."

The last thirty years have seen the period of greatest activity in the study of biology. Among other matters, we have seen the rise of definite knowledge of the process of heredity, and its application to the formation and improvement of races of men and animals. From our

[1] Address (given in German) before the Weltcongress von Freien Christentum, Berlin, August 7, 1910.

scientific knowledge, men have developed the fine art of selective breeding. With men, as with animals, "Like the seed is the harvest." In every vicissitude of race of men or of breed of animals, it is always those who are left who determine what the future shall be.

All progress in whatever direction is conditioned on selective breeding. There is no permanent advance not dependent on advance in the type of parenthood. There is no decline except that arising from breeding from the second-best instead of the best. The rise and fall of races of men in history is, in a degree, conditioned on such elements as determine the rise and fall of a breed of cattle or of a strain of horses. As progress in blood is conditioned on normal selection or the choice of the best for parenthood, so racial decline is conditioned on reversal of selection, the choice of the worst for survival.

Always and ever, says Novicow, "war brings about the reversal of selection." These traits of character, physical strength, agility, courage, dash, patriotism, desired in the soldier, are lost in the race which decrees the destruction of the soldierly. The delusion that war in one generation sharpens the edge of warriorhood in the next generation, has no biological foundation. The man who is left determines always the future.

Once, on the flanks of the Apennines, there dwelt a race of free men, fair and strong, self-reliant and confident. They were men of courage and men of action—men "who knew no want they could not fill for themselves." "They knew none on whom they looked down, and none to whom they regarded themselves inferior." And for all things which men could accomplish, these plowmen of the Tiber and the Apennines felt themselves fully competent and adequate. "*Vir,*" they called themselves in their own tongue, and *virile, virilis,* men like them are called to this day. It was the weakling and the slave who was crowded to the wall; the man of courage begat descendants. In each generation and from generation to generation the human harvest was good. And the great wise king who ruled them; but here my story halts—for there was no king. There could be none. For it was written, men fit to be called men, men who are *Viri,* "are too self-willed, too independent, too self-centered to be ruled by anybody but themselves." Kings are for weaklings, not for men. Men free-born control their own destinies. "The fault is not in our stars, but in ourselves, that we are underlings." For it was later said of these same days: "There was a Brutus once, who would have brooked the Eternal Devil to take his seat in Rome, as easily as a king." And so there was no king to cherish and control these men his subjects. The spirit of freedom was the only ruler they knew, and this spirit being herself metaphoric called to her aid the four great genii which create and recreate nations. Variation was ever at work, while heredity held fast all that she developed. Segregation in her mountain fastnesses held the world away, and selection chose the best and for the best purposes, casting aside the weakling, and the slave, holding the man for the man's work, and ever the man's work was at home, building the cities, subduing the forests, draining the marshes, adjusting the customs and statutes, preparing for the new generations. So the men begat sons of men after their own fashion, and the men of strength and courage were ever dominant. The Spirit of Freedom is a wise master; he cares wisely for all that he controls.

So in the early days, when Romans were men, when Rome was small, without glory, without riches, without colonies and without slaves, these were the days of Roman greatness.

Then the Spirit of Freedom little by little gave way to the Spirit of Domination. Conscious of power, men sought to exercise it, not on themselves but on one another. Little by little, this meant banding together, aggression, suppression, plunder, struggle, glory and all that goes with the pomp and circumstance of war. The individuality of men was lost in the aggrandizement of the few. Independence was swallowed up in ambition, patriotism came to have a new meaning. It was transferred from the hearth and home to the trail of the army.

It does not matter to us now what were the details of the subsequent history of Rome. We have now to consider only a single factor. In science, this factor is known as "reversal of selection." "Send forth the best ye breed!" That was the word of the Roman war-call. And the spirit of domination took these words literally, and the best were sent forth. In the conquests of Rome, *Vir,* the real man, went forth to battle and to the work of foreign invasion; *Homo,* the human being, remained on the farm and in the workshop and begat the new generations. Thus "*Vir* gave place to *Homo.*" The sons of real men gave places to the sons of scullions, stable-boys, slaves, camp-followers and the riff-raff of those the great victorious army did not want.

The fall of Rome was not due to luxury, effeminacy, corruption, the wickedness of Nero and Caligula, the weakness of the train of Constantine's worthless descendants. It was fixed at Philippi, when the spirit of domination was victorious over the spirit of freedom. It was fixed still earlier, in the rise of consuls and triumvirates and the fall of the simple, sturdy, self-sufficient race who would brook no arbitrary ruler. When the real men fell in war, or were left in far-away colonies, the life of Rome still went on. But it was a different type of Roman which continued it, and this new type repeated in Roman history its weakling parentage.

Thus we read in Roman history of the rise of the mob and of the emperor who is the mob's exponent. It is not the presence of the emperor which makes imperialism. It is the absence of the people, the want of men. Babies in their day have been emperors. A wooden image would serve the same purpose. More than once it has served it. The decline of a people can have but one cause, the decline in the type from which it draws its sires. A herd of cattle can degenerate in no other way than this, and a race of men is under the same laws. By the rise in absolute power, as a sort of historical barometer, we may mark the decline in the breed of the people. We see this in the history of Rome. The conditional power of Julius Caesar, resting on his own tremendous personality, showed that the days were past of Cincinnatus and of Junius Brutus. The power of Augustus showed the same. But the decline went on. It is written that "the little finger of Constantine was thicker than the loins of Augustus." The emperor in the time of Claudius and Caligula was not the strong man who held in check all lesser men and organizations. He was the creature of the mob, and the mob, intoxicated with its own work, worshipped him as divine. Doubtless the last emperor, Augustulus Romulus, before he was thrown into the scrap-heap of history, was regarded in the mob's eyes and his own as the most godlike of them all.

What have the historians to say of these matters? Very few have grasped the full significance of their own words, for very few have looked on men as organisms, and on nations as dependent on the specific character of the organisms destined for their reproduction.

So far as I know, Benjamin Franklin was the first to think of man thus as an inhabitant, a species in nature among other species and dependent on nature's forces as other animals and other inhabitants must be.

In Otto Seeck's great history of "The Downfall of the Ancient World" ("Der Untergang der Antiken Welt"), he finds this downfall due solely to the rooting out of the best ("Die Ausrottung der Besten"). The historian of the "Decline and Fall of the Roman Empire," or any other empire, is engaged solely with the details of the process by which the best men are exterminated. Speaking of Greece, Dr. Seeck says, "A wealth of force of spirit went down in the suicidal wars." "In Rome, Marius and Cinna slew the aristocrats by hundreds and thousands. Sulla destroyed the democrats, and not less thoroughly. Whatever of strong blood survived fell as an offering to the proscription of the Triumvirate." "The Romans had less of spontaneous force to lose than the Greeks. Thus desolation came to them sooner. Whoever was bold enough to rise politically in Rome was almost without exception thrown to the ground. Only cowards remained and from their brood came forward the new generations. Cowardice showed itself in lack of originality and in slavish following of masters and traditions."

The Romans of the Republic could not have made the history of the Roman Empire. In their hands it would have been still a republic. Could they have held aloof from world-conquering schemes, Rome might have remained a republic, enduring even to our own day. The seeds of destruction lie not in the race nor in the form of government, but in the influences by which the best men are cut off from the work of parenthood.

"The Roman Empire," says Seeley, "perished for want of men." The dire scarcity of men is noted even by Julius Cæsar. And at the same time it is noted that there are men enough. Rome was filling up like an overflowing marsh. Men of a certain type were plenty, "people with guano in their composition," to use Emerson's striking phrase, but the self-reliant farmers, the hardy dwellers on the flanks of the Apennines, the Roman men of the early Roman days, these were fast going, and with the change in the breed came the change in Roman history.

"The mainspring of the Roman army for centuries had been the patient strength and courage, capacity for enduring hardships, instinctive submission to military discipline of the population that lined the Apennines."

With the Antonines came "a period of sterility and barrenness in human beings." "The human harvest was bad." Bounties were offered for marriage. Penalties were devised against race-suicide. "Marriage," says Metellus, "is a duty which, however painful, every citizen ought manfully to discharge." Wars were conducted in the face of a declining birth rate, and this decline in quality and quantity of the human harvest engaged very early the attention of the wise men of Rome.

"The effect of the wars was that the ranks of the small farmers were decimated, while the number of slaves who did not serve in the army multiplied" (Bury).

Thus "*Vir* gave place to *Homo*," real men to mere human beings. There were always men enough such as they were. "A hencoop will be filled, whatever the (original) number of hens," said Benjamin Franklin. And thus the mob filled Rome. No wonder the mob-leader, the mob-hero, rose in relative importance. No wonder "the little finger of Constantine was thicker than the loins of Augustus." No wonder that "if Tiberius chastised his subjects with whips, Valentinian chastised them with scorpions."

"Government having assumed godhead took at the same time the appurtenances of it. Officials multiplied. Subjects lost their rights. Abject fear paralyzed the people and those that ruled were intoxicated with insolence and cruelty." "The worst government is that which is most worshipped as divine." "The emperor possessed in the army an overwhelming force over which citizens had no influence, which was totally deaf to reason or eloquence, which had no patriotism because it had no country, which had no humanity because it had no domestic ties." "There runs through Roman literature a brigand's and barbarian's contempt for honest industry." "Roman civilization was not a creative kind, it was military, that is destructive." What was the end of it all? The nation bred real men no more. To cultivate the Roman fields "whole tribes were borrowed." The man of the quick eye and the strong arm gave place to the slave, the scullion, the pariah, the man with the hoe, the man whose lot does not change because in him there lies no power to change it. "Slaves have wrongs, but freemen alone have rights." So at the end the Roman world yielded to the barbaric, because it was weaker in force. "The barbarians settled and peopled the barbaric rather than conquered it." And the process is recorded in history as the fall of Rome.

"Out of every hundred thousand strong men, eighty thousand were slain. Out of every hundred thousand weaklings, ninety to ninety-five thousand were left to survive." This is Dr. Seeck's calculation, and the biological significance of such mathematics must be evident at once. Dr. Seeck speaks with scorn of the idea that Rome fell from the decay of old age, from the corruption of luxury, from neglect of military tactics or from the over-diffusion of culture.

It is inconceivable that the mass of Romans suffered from over-culture. In condemning the sinful luxury of wealthy Romans, we forget that the trade-lords of the fifteenth and sixteenth centuries were scarcely inferior in this regard to Lucullus and Apicius, their waste and luxury not constituting the slightest check to the advance of the nations to which these men belonged. The people who lived in luxury in Rome were scattered more thinly than in any modern state of Europe. The masses lived at all times more poorly and frugally because they could do nothing else. Can we conceive that a war force of untold millions of people is rendered effeminate by the luxury of a few hundreds?

Too long have historians looked on the rich and noble as making the fate of the world. Half the Roman Empire was made up of rough barbarians untouched by Greek or Roman culture. (Seeck.)

Whatever the remote and ultimate cause may have been, the immediate cause to which the fall of the empire can be traced is a physical not a moral decay. In valor, discipline and science the Roman armies remained what they had always been and the peasant emperors of Illyricum were worthy successors of Cincinnatus and Caius Marius. But the problem was, how to replenish those armies. Men were wanting. The empire perished for want of men. (Seeley.)

Does history ever repeat itself? It always does if it is true history. If it does not we are dealing not with history, but with mere succession of incidents. Like causes produce like effects, just as often as man may choose to test them. Whenever men use a nation for the test, poor seed yields a poor fruition. Where the weakling and the coward survive in human history, there "the human harvest is bad," and it can never be otherwise.

The finest Roman province, a leader in the Roman world, was her colony of Hispania. What of Spain in history? What of Spain to-day? "This is Castile," said a Spanish writer, "she makes men and wastes them." "This sublime and terrible phrase," says another writer, "sums up Spanish history."

In 1630, according to Captain Calkins, the Augustinian friar, La Puente, thus summed up the fate of Spain:

> Against the credit for redeemed souls, I set the cost of armadas and the sacrifice of soldiers and friars sent to the Philippines. And this I count the chief loss: for mines give silver and forests give timber, but only Spain gives Spaniards, and she may give so many that she may be left desolate and constrained to bring up strangers' children instead of her own.

Another of the noblest of Roman provinces was Gallia, the favored land, in which the best of the Romans, the Franks and the Northmen, have mingled their blood to produce a nation of men, hopefully leaders in the arts of peace, fatally leaders also in the arts of war.

In that clever volume of his, Demolins asks: "In what constitutes the superiority of the Anglo-Saxon?" Before we answer this, we may ask, "In what constitutes the inferiority of races not Anglo-Saxon?" If we admit that inferiority exists in any degree, may we not find in the background the causes of the fall of Greece, the fall of Rome, the fall of Spain? We find the spirit of domination, the spirit of glory, the spirit of war, the final survival of subserviency, of cowardice and of sterility. The man who is left holds in his grasp the history of the future. The evolution of a race is always selective, never collective. Collective evolution among men or beasts, the movement upward or downward of the whole as a whole, irrespective of training or selection, does not exist. As Lepouge has said, "It exists in rhetoric, not in truth nor in history."

The survival of the fittest in the struggle for existence is the primal moving cause of race progress and of race changes. In the red stress of human history, this natural process of selection is sometimes reversed. A reversal of selection is the beginning of degradation. It is degradation itself. Can we see the fall of Rome in any part of the history of modern Europe? Let us look again at the history. A single short part of it will be enough. It will give us the clue to the rest.

In the Wiertz gallery in Brussels is a wonderful painting, dating from the time of Waterloo, called Napoleon in Hell. It represents the great marshal with folded arms and face unmoved descending slowly to the land of the shades. Before him, filling all the background of the picture with every expression of countenance, are the men sent before him by the unbridled ambition of Napoleon. Three millions and seventy thousand there were in all—so history tells us—more than half of them Frenchmen. They are not all shown in one picture. They are only hinted at. And behind the millions shown or hinted at are the millions on millions of men who might have been and are not—the huge widening human wedge of the possible descendants of the men who fell in battle. These men of Napoleon's armies were the youth without blemish, "the best that the nation could bring," chosen as "food for powder," "ere evening to be trampled like the grass," in the rush of Napoleon's great battles. These men came from the plow, from the work-shop, from the school, the best there were—those from eighteen to thirty-five years of age at first, but afterwards the older and the younger. "A boy will stop a bullet as well as a man"; this maxim is accredited to Napoleon. "The more vigorous and well born a young man is," says Novicow, "the more normally constituted, the greater his chance to be slain by musket or magazine, the rifled cannon and other similar engines of civilization." Among those destroyed by Napoleon were "the elite of Europe." "Napoleon," said Otto Seeck, "in a series of years seized all the young of high stature and left them scattered over many battle fields, so that the French people who followed them are mostly men of smaller stature. More than once in France since Napoleon's time has the military limit been lowered."

Says Le Goyt, "It will take long periods of peace and plenty before France can recover the tall statures mowed down in the wars of the republic and the first empire."

I need not tell again the story of Napoleon's campaigns. It began with the justice and helpfulness of the Code Napoleon, the prowess of the brave lieutenant whose military skill and intrepidity had caused him to deserve well of his nation.

The spirit of freedom gave way to the spirit of domination. The path of glory is one which descends easily. Campaign followed campaign, against enemies, against neutrals, against friends. The trail of glory crossed the Alps to Italy and to Egypt, crossed Switzerland to Austria, crossed Germany to Russia. Conscription followed victory and victory and conscription debased the human species. "The human harvest was bad." The first consul became the emperor. The servant of the people became the founder of the dynasty. Again conscription after conscription. "Let them die with arms in their hands. Their death is glorious, and it will be avenged. You can always fill the places of soldiers." These were Napoleon's words when Dupont surrendered his army in Spain to save the lives of a doomed battalion.

More conscription. After the battle of Wagram, we are told, the French began to feel their weakness, the Grand Army was not the army which fought at Ulm and Jena. "Raw conscripts raised before their time and hurriedly drafted into the line had impaired its steadiness."

On to Moscow,[2] "amidst ever-deepening misery they struggled on, until of the 600,000 men who had proudly crossed the Niemen for the conquest of Russia, only 20,000 famished, frost-bitten, unarmed spectres staggered across the bridge of Korni in the middle of December."

"Despite the loss of the most splendid army marshalled by man,

[2] These quotations are from the "History of Napoleon," I., by J. H. Rose.

Napoleon abated no whit of his resolve to dominate Germany and discipline Russia. . . . He strained every effort to call the youth of the empire to arms . . . and 350,000 conscripts were promised by the Senate. The mighty swirl of the Moscow campaign sucked in 150,000 lads of under twenty years of age into the devouring vortex." "The peasantry gave up their sons as food for cannon." But "many were appalled at the frightful drain on the nation's strength." "In less than half a year after the loss of half a million men a new army nearly as numerous was marshalled under the imperial eagles. But the majority were young, untrained troops, and it was remarked that the conscripts born in the year of Terror had not the stamina of the earlier levies. Brave they were, superbly brave, and the emperor sought by every means to breathe into them his indomitable spirit." "Truly the emperor could make boys heroes, but he could never repair the losses of 1812." "Soldiers were wanting, youths were dragged forth." The human harvest was at its very worst.

The unfailing result of this must be the failure in the nation of those qualities most sought in the soldier. The result is a crippled nation, "Une nation blessée," to use the words of an honored professor in the University of Paris. The effect would not appear in the effacement of art or science, or creative imagination. Men who lead in these regards are not drawn by preference or by conscription to the life of the soldier. If we cut the roots of a tree, we shall not affect, for a time at least, the quality of its flowers or its fruits. We are limiting its future, rather than changing its present. In like manner does war affect the life of nations. It limits the future, rather than checks the present.

Those who fall in war are the young men of the nations, the men between the ages of eighteen and thirty-five, without blemish so far as may be—the men of courage, alertness, dash and recklessness, the men who value their lives as nought in the service of the nation. The man who is left is for better and for worse the reverse of all this, and it is he who determines what the future of the nation shall be.

However noble, encouraging, inspiring, the history of modern Europe may be, it is not the history we should have the right to expect from the development of its racial elements. It is not the history that would have been made by these same elements released from the shadow of the reversed selection of fratricidal war. And the angle of divergence between what might have been and what has been, will be determined by the percentage of strong men slain on the field of glory.

And all this applies, not to one nation nor to one group of nations alone, but in like degree to all nations, which have sent forth their young men to the field of slaughter. As with Greece and Rome, as with France and Spain, as with Mauritania and Turkestan, so with Germany and England, so with all nations who have sent forth "the best they breed" to the foreign service, while cautious, thrifty mediocrity filled up the ranks at home.

In his charming studies of "Feudal and Modern Japan," Mr. Arthur Knapp, of Yokohama, returns again and again to the great marvel of Japan's military prowess after more than two hundred years of peace. This was shown in the Chinese war. It has been more conclusively shown on the fields of Manchuria since Mr. Knapp's book was written. It is astonishing to him that, after more than six generations in which physical courage has not been demanded, these virile virtues should be found unimpaired. We can readily see that this is just what we should expect. In times of peace there is no slaughter of the strong, no sacrifice of the courageous. In the peaceful struggle for existence there is a premium placed on these virtues. The virile and the brave survive. The idle, weak and dissipated go to the wall. "What won the battles on the Yalu, in Korea or Manchuria," says the Japanese, Nitobe, "was the ghosts of our fathers guiding our hands and beating in our hearts. They are not dead, these ghosts, those spirits of our warlike ancestors. Scratch a Japanese, even one of the most advanced ideas, and you will find a Samurai." If we translate this from the language of Shintoism to that of science we find it a testimony to the strength of race-heredity, the survival of the ways of the strong in the lives of the self-reliant.

If after two hundred years of incessant battle Japan still remained virile and warlike, that would indeed be the marvel. But that marvel no nation has ever seen. It is doubtless true that warlike traditions are most persistent with nations most frequently engaged in war. But the traditions of war and the physical strength to gain victories are very different things. Other things being equal, the nation which has known least of war is the one most likely to develop the "strong battalions" with whom victory must rest.

As Americans we are more deeply interested in the fate of our mother country than in that of the other nations of Europe.

What shall we say of England and of her relation to the reversed selection of war?

Statistics we have none, and no evidence of tangible decline that Englishmen will not indignantly repudiate. When the London press in the vacation season fills its columns with editorials on English degeneration, it is something else to which these journalists refer. Their problem is that of the London slums, of sweat-shops and child-labor, of wasting overwork and of lack of nutrition, of premature old age and of sodden drunkenness—influences which bring about the degeneration of the individual, the inefficiency of the social group, but which for the most part leave no trace in heredity and are therefore no factor in the degeneration of the race. Such degradation is at once cause, effect and symptom—a sign of racial inadequacy, a cause of further enfeeblement and an effect of unjust and injurious social, political and industrial conditions in the past.

But the problem before us is not the problem of the slums. What mark has been left on England by her great struggles for freedom and by the thousand petty struggles to impose on the world the semblance of order called "Pax Britannica," the British peace?

To one who travels widely through the counties of England some part of the cost is plain.

> There's a widow in sleepy Chester
> Who mourns for her only son;
> There's a grave by the Pabeng River—
> A grave which the Burmans shun.

This is a condition repeated in every village of England, and its history is recorded on the walls of every parish church. Everywhere can be seen tablets in memory of young men—gentlemen's sons from Eton and Rugby and Winchester and Harrow, scholars from Oxford and Cambridge, who have given up their lives in some far-off petty war. Their bodies rest in Zululand, in Cambodia, in the Gold Coast, in the Transvaal. In England only they are remembered. In the parish churches these records are numbered by the score. In the cathedrals they are recorded by the thousand. Go from one cathedral town to another—Canterbury, Winchester, Chichester, Exeter, Salisbury, Wells, Ely, York, Lincoln, Durham, Litchfield, Chester (what a wonderful series of pictures this list of names calls up!), and you will find always the same story, the same sad array of memorials to young men. What would be the effect on England if all of these "unreturning brave" and all that should have been their descendants could be numbered among her sons to-day? Doubtless not all of these were young men of character. Doubtless not all are worthy even of the scant glory of a memorial tablet. But most of them were worthy. Most of them were brave and true, and most of them looked out on life with "frank blue Briton eyes."

This too we may admit, that war is not the only destructive agency in modern society, and that in the struggle for existence the England of to-day has had many advantages which must hide or neutralize the waste of war.

It suggests the inevitable end of all empire, of all dominion of man over man by force of arms. More than all who fall in battle or are wasted in the camps, the nation misses the "fair women and brave men" who should have been the descendants of the strong and the manly. If we may personify the spirit of the nation, it grieves most not over its "unreturning brave," but over those who might have been but never were, and who, so long as history lasts, can never be.

It is claimed that by the law of probabilities as developed by Quetelet, there will appear in each generation the same number of potential poets, artists, investigators, patriots, athletes and superior men of each degree. But this law has no real validity. Its pertinence involves the theory of continuity of paternity, that in each generation a percentage practically equal of men of superior force or superior mentality should survive to take the responsibilities of parenthood. Otherwise Quetelet's law becomes subject to the operation of another law, the operation of reversed selection, or the biological "law of diminishing returns." In other words, breeding from an inferior stock is the sole agency in race degeneration, as selection natural or artificial along one line or another is the sole agency in race progress.

And all laws of probabilities and of averages are subject to a still higher law, the primal law of biology, which no cross-current of life can overrule or modify: Like the seed is the harvest.

And because this is true, arises the final and bitter truth: "Wars are not paid for in war time. The bill comes later!"

THE PROGRESS OF SCIENCE

ACADEMIC AND INDUSTRIAL EFFICIENCY

The Carnegie Foundation is certainly doing what it can to disturb the somnambulance which is supposed to characterize academic circles. It promises length of service pensions to professors and then decides not to pay them; its trustees pass resolutions and quite different action is announced in the annual report; it tells universities to do this, that and the other, if they want its pensions. There was recently published a report informing us that most of the medical schools in the country should be suppressed, and we now have a bulletin telling us how universities should introduce the industrial efficiency which the author optimistically assumes to characterize our manufacturing concerns.

This publication, like others from the same source, is really interesting. It is an advantage for academic problems to be discussed from all sides and that complete publicity should be given to financial management. It is, however undesirable for an institution having largesses to bestow to assume powers either inquisitorial or dictatorial. In the present case it is fair to state that the president of the foundation says that he refrains from discussing the merits of the report made and published under its direction.

The author, Mr. M. L. Cooke, is an engineer who specializes in the organization and management of industrial establishments. He takes himself and his methods so seriously that it is difficult to treat them with the consideration which they may deserve. It is evident from the principle of the "cost per unit hour" that a university in which a thousand-dollar instructor is teaching a hundred students is five hundred times as efficient as one in which a five-thousand-dollar professor is proposing a problem for research to a single man; but it is not clear how one can deduce from this principle that "there is a distinct disadvantage to undergraduate students to be near research work." But perhaps this is because research work does not set an example of efficiency, the universities not yet having adopted Mr. Cooke's plan of a "general research board" and "a director of research," "to pass on the expediency of undertaking any given project, and to keep constant track of the progress of work and of its cost."

Mr. Cooke commends one professor who told him "that if at a lecture the students began to get drowsy, he gave them a little more air," but it is not clear that the cost per unit hour would have been increased if the air had been let in sooner. This particular professor is also highly praised for keeping his lecture-room extraordinarily neat; but it appears elsewhere in the report that under these circumstances he required four assistants to help in the preparation of a lecture.

We are told by Mr. Cooke that only at one university "was there anything to impress me with the snap and vigor of the business administration." If the tables in the report are correct, this university pays its teachers less than Harvard, but spends more than twice as much in its administration, namely, $258,456.12 a year, about half what it pays its teachers. This university, the combined cost of whose administration and teaching is greater than at Harvard, has about half as many scientific men of distinction on its faculty. Indeed, in one case at least Mr. Cooke's observation is not bad, for he naïvely says: "At those schools where there were the largest number of "big men" I found what seemed to me to be the least desirable systems of management." Mr. Cooke would remedy this by arranging matters so "that when a man has ceased to be efficient he must be retired, as he would in any other line of work"; but he does not tell us who would be responsible for dismissing professors or whether under these circumstances professors in our leading universities might not properly expect salaries equal to those of our leading engineers, physicians and lawyers.

It should be understood that these remarks and quotations give only one side of Mr. Cooke's report, which is in many respects a document worth reading. The usefulness of our universities should be increased; their money is not always spent to the best advantage. It seems to be generally true that efficiency is inversely as the size of the "concern." The writer of this note has recently had dealings with a department store, a publishing house and an express company, and he can assure Mr. Cooke and the Carnegie Foundation that there is even more urgent need for missionary labors on behalf of efficiency elsewhere than in the university. Efficiency is desirable everywhere; but it is only a means to an end. The university stands for higher things—scholarship, research, service, leadership, ideals, honor. It is doubtful whether the further elaboration of department-store methods in the university will even reduce the "cost per unit hour," if "overhead charges" are included. The solution is the reverse of that proposed by Mr. Cooke. The department should have autonomy and the individual freedom. Only thus will the best men be drawn to the universities and be led to do their best work.

THE MOUNT WILSON CONFERENCE OF THE SOLAR UNION

The fourth conference of the International Union for Solar Research was held at the Solar Observatory of the Carnegie Institution, Mount Wilson, California, from August 31 to September 2, 1910. The attendance was large, 37 delegates from eleven foreign countries being recorded on the official list, together with 46 Americans. Many of the latter, though not members of the union, had accepted its invitation to attend the conference.

Nearly half the delegates crossed the continent together, as many had attended the meeting of the Astronomical and Astrophysical Society of America at Harvard (August 17–19). This afforded opportunities for informal conferences and discussions almost equal in value to those provided by the conference itself.

On Monday, August 29, the members of the conference visited the laboratories and shops of the Solar Observatory, which are in Pasadena at the foot of the mountain. Among the things of greatest interest may be mentioned the exceedingly well-equipped spectroscopic laboratory, the massive machinery for grinding the great 100-inch mirror and a wealth of photographs, some of which showed the enormous light-gathering power of the great 60-inch reflector now installed on the mountain.

The afternoon was pleasantly occupied by a garden party given by Professor and Mrs. Hale, and on the following morning the party, numbering nearly 100, began the 5,000-foot climb to the observatory, some in carriages, some on horseback and a few hardy souls on foot. The hotel on the summit, though crowded to the limit, provided all with very comfortable accommodation.

No formal papers were read at the sessions of the conference, which were devoted to the reports of committees and to questions of general policy; but the larger part of the day was free for conferences of an informal nature, which were most valuable, especially to the younger men.

The first official session was on Wednesday morning. Professors Pickering, Campbell and Frost (directors of the Harvard, Lick and Yerkes observatories) were elected chairmen for the three days of the meeting, and Messrs. Puiseux (of Paris), Konen (Münster) and Adams (Mt. Wilson), secretaries of the meeting. All formal business was announced in English, French and German, and the three languages were used in the discussions, which emphasized the international character of the gathering.

Dr. Hale made the opening address. He welcomed the visitors to the observatory, and described the work in progress there, dwelling especially on the recent discoveries that sun-spots are the centers of a vortical movement in the upper layers of the solar atmosphere, and the seat of strong magnetic fields, and describing the new "tower telescope," of 150 feet focal length, mounted vertically on a tower, every member of whose framework is completely surrounded by that of an outer tower, protecting it from vibration and other disturbances, while the spectroscopic apparatus, of 75 feet focal length, is in a deep well under the tower, effectually protected from changes of temperature and other perturbations.

The report of the committee on standard wave-lengths was presented by Professor Kayser (Bonn), and it was voted that when three independent measurements by the interference method of the lines of the iron arc are available, the arithmetical mean of the three shall be adopted as international standards of the second order (Michelson's determination for the red cadmium line being the primary standard). Standards of the third order are to be determined by interpolation between these and a complete system of very exact reference points throughout the spectrum thereby obtained.

Dr. Abbot, of the Smithsonian Astrophysical Observatory on Mount Wilson, lectured that evening on the solar constant of radiation, and presented a committee report dealing with the same subject on the following morning. After correcting for the absorption of heat in passing through our atmosphere (a very difficult problem, now in a fair way toward solution) the heat received from the sun appears to be slightly less than two gram-calories per square centimeter per minute. The Mount Wilson observations, however, show changes of short and irregular period (a few days) which exceed the errors of observation. It is exceedingly desirable to establish a second station some distance away (say in Mexico) where simultaneous observations may be made, to determine whether these changes are of solar or atmospheric origin.

The report of the committee on the spectra of sun-spots was presented by Professor Fowler (South Kensington). The principal feature of interest was the remarkable constancy, even in small details, of the spectrum shown by different spots.

On the second evening (Thursday) Professor Kapteyn (Groningen) lectured on "Star-streams among Stars of the Orion Type," showing that in a large region of the southern sky (including Scorpio, Centaurus and the Southern Cross) 85 per cent. of the stars of this spectral type (supposed to be the hottest) are moving together in space, their actual motions being very nearly equal and parallel; while in Perseus and neighboring constellations 95 per cent. of the stars of the same type have a similar common drift, but of different magnitude and direction. The velocity of these drifts can be found from spectroscopic observations, which makes it possible to determine the distances of these remote stars, which in some cases appear to be as great as 500 light-years—far beyond the possibility of direct measurement.

On Friday reports from committees on solar rotation and on spectroheliographic work were presented, and, the regular business being at an end, the question of the extension of the work

ASTRONOMERS ON MOUNT WILSON

Dr Hale near the center; on his left Mrs. Kapteyn and Mrs. Fleming; on h's right Messrs. Pickering, Backlund, Kayser and Turner; further on, Messrs. Rydberg, Wolfer, Küstner, Hartmann, Puiseux and Frost. Above, near the door, are Messrs. Ames, Kosen, Fowler, Deslandres, Belpolsky, Campbell, Ricco, Schwarzschild and Schlesinger. Further to the left are Messrs. Fabry, Hills, Abbot, Larmor, Dyson, Barnard, Newell and Pringsheim.

of the union to the study of stellar spectra was discussed at some length. Opinion in favor of such a step appeared to be almost unanimous, and, on motion of Professor Schwarzschild (Potsdam), it was formally resolved "that the Solar Union extend its sphere of activity so as to include astrophysics generally," and this was followed up by the appointment of a committee on the classification of stellar spectra.

Invitations to hold the next meeting at Bonn, Barcelona and Rome were presented, and it was decided to meet at the first, in the summer of 1913—the exact date to be determined by the executive committee.

The former committees of the union were in most cases reappointed, a number of new members being added. The new committee on stellar spectra includes Messrs. Pickering (chairman), Adams, Campbell, Frost, Hale, Hamer, Hartmann, Kapteyn, Küstner, Newall, Plaskett, Russell, Schlesinger (secretary) and Schwarzschild, with power to add to their number.

Resolutions of thanks—proposed in very felicitous speeches—completed the business, and the conference adjourned, to reassemble on Saturday evening at Pasadena as the guests of Dr. and Mrs. Hale at a dinner, which brought the proceedings to a close.

The only cloud upon an otherwise flawless week was the ill-health of Dr. Hale, who was able to attend only the opening session of a conference whose success was above all things the result of his hospitable preparations.

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. Charles Otis Whitman, head of the department of zoology of the University of Chicago and lately director of the Woods Hole Marine Biological Station; of Dr. Christian Archibald Herter, professor of pharmacology and therapeutics in the College of Physicians and Surgeons of Columbia University; of Dr. Octave Chanute, of Chicago, known for his important contributions to scientific aviation, and of Dr. Angelo Mosso, professor of physiology in the University of Turin.

A memorial has been erected at the National Bacteriological Institute in the City of Mexico to Howard T. Ricketts, who at the time of his death was assistant professor of pathology in the University of Chicago and professor-elect of pathology in the University of Pennsylvania. His death was caused by typhus fever, which he contracted while conducting researches in this disease.

Dr. Edgar F. Smith, for twenty-two years professor of chemistry in the University of Pennsylvania and for twelve years vice-provost, has been elected provost in succession to Dr. C. C. Harrison.—Mr. R. A. Sampson, F.R.S., professor of mathematics and astronomy in the University of Durham, has been named astronomer royal for Scotland in succession to Mr. F. W. Dyson, F.R.S.

At the celebration of the centenary of the University of Berlin degrees were conferred on three American men of science—the degree of doctor of philosophy on Dr. George E. Hale, director of the Mount Wilson Solar Observatory, and on Dr. Bailey Willis, of the U. S. Geological Survey, and the degree of doctor of medicine and surgery on Dr. Theodore W. Richards, professor of chemistry in Harvard University.—Dr. Henry F. Osborn, of Columbia University and the American Museum of Natural History, and Professor E. B. Wilson, of Columbia University, have been elected corresponding members of the Munich Academy of Sciences.—Mme. Curie is a candidate for the *fauteuil* at the Academy of Sciences, rendered vacant by the death of M. Gernez.

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THE DISCIPLINARY VALUE OF GEOGRAPHY

By Professor W. M. DAVIS

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Part I. The Science of Geographical Investigation

Educational Values.—Any study that is worthy of a place in a university must have a value of its own, must stand in a serviceable relation to other subjects, and must offer a serious mental discipline for those who follow it. The modern treatment of geography by explanatory instead of by empirical methods, and in view of an evolutionary instead of a teleological philosophy, satisfies all these requirements. That geography has a value of its own is sufficiently indicated by the abundance of useful and interesting material that an otherwise well-prepared student may acquire from it, and from no other source. That it stands in a serviceable relation to other subjects is proved by the fundamental position that it occupies with respect to biology and history, as well as to commerce and diplomacy. That it provides a serious mental discipline will, it is hoped, be apparent to any one who cares to read the following pages. A discussion of the science of geographical investigation, here presented with particular respect to the study of land forms, but equally applicable to other divisions of the subject, will show that geography, like various other sciences, gives abundant exercise to various mental faculties, such as observation, invention, deduction, comparison and judgment; while a consideration of the art of geographical presentation will show that geography, like other sciences, encourages the development of various styles of composition, such as narrative, inductive, analytical, systematic and regional, each of which is particularly well adapted to the exposition of certain geographical problems.

The Student and the World.—It has been well remarked by an experienced university professor, that an advanced student would profit greatly if he guarded himself against a too great absorption and isolation in his investigation of a limited field of study, by giving conscious attention to the presentation of his results in the best possible form for their full appreciation by so many of the rest of the world as may be interested in them; for he would be thereby placed in a more sympathetic relation with at least some of the rest of humanity, from whom he might otherwise remain too long estranged. Success in this effort is greatly promoted if the student recognizes the essential differences between investigation, which tends to isolate him from the world, and presentation, which ought to bring him into relation with it. The chief of these differences may be here pointed out, with particular relation to geographical problems.

Investigation.—During the progress of an investigation the student is properly enough alone with his subject for a large part of his time, whether he is in the field, the laboratory or the library. This is quite as it should be, for if during this period his attention is much distracted by outside matters, he can not develop a single-minded concentration of his best efforts on his work; he can not form that close intimacy with his problem which comes from uninterrupted association with it. Several weeks or months may be devoted to reaching his conclusions, and during this period the student may rightly enough find himself increasingly absorbed in his work and correspondingly withdrawn from outside relations; but he must remember that isolation does not involve secrecy. The pleasure of progress and discovery is increased by sharing it with appropriate companions. If some ideas are thus planted in better soil than that from which they sprang, let the larger growth that they reach there cause rejoicing, not envy; for as Gilbert has so well said in an admirable essay on "Scientific Method": "It is only the man of small caliber who has no ideas to spare, and secretiveness in matters of science is ordinarily a confession of weakness."[1]

In the course of progress, facts and theories are come upon in an irregular and unforeseen order; only towards the close of his work is the student in a position to reconsider everything that he has learned and to give it all a well-ordered arrangement. During his advance he must ever be alert in discovering new facts, open-minded towards new ideas, critical of every statement, jealously watchful of his mental independence, judicial in reaching conclusions: but in all these activities, his work should be carried on for the most part alone, for only when isolated is he sufficiently thrown on his own resources; and only when thus depending on himself can he learn whether he is really able to carry on an independent investigation. His opinions may fre-

[1] G. K. Gilbert, "The Inculcation of Scientific Method by Example," *Amer. Journ. Sci.*, XXXI., 1886, 284–299.

quently change as his collection of facts and his invention of explanations advance; new facts and new ideas may frequently call for the revision of earlier facts and ideas, and for the change of first-formed opinions; all such revision and change are best accomplished when the student is alone with his problem. At the end of his study, the net results gained may appear to be of small volume, in view of the time and labor spent in reaching them; but if they include a matured and well-balanced judgment on the problem under discussion, as well as an intimate acquaintance with its sources of material, a comprehensive knowledge of its historical development, and a close familiarity with all the factors involved in its investigation, the time and labor will have been well expended.

Presentation.—Occasion then arises for the oral or printed presentation of the results of all this independent work, in form for their best understanding by others. The student must then emerge from his isolation, in which the world may have seemed to him to be occupied chiefly by his problem and himself; he must recognize that the real world is crowded with other problems and other workers, among which he and his interests may be rudely jostled in course of finding the place that they deserve. He must now awake to a realization of his surroundings, and consider particularly what sort of presentation will place his results most effectively and favorably before the public. He no longer has to consider the nature of his own work; that he has done sufficiently already. He has now to consider the nature of other persons whose interests are more or less akin to his own, in order to discover how he can best bring his work before them. When his presentation has been made, he will learn that those of his hearers or readers who meet him with unselfish sympathy and just appreciation become his most helpful and encouraging friends; and he ought at the same time to learn what his own bearing should be when it is his turn to listen to reports by his colleagues on their work. We will here examine briefly the requirements of an oral presentation, postponing the discussion of a printed report to a later page.

When a student rises to make an oral report in the presence of his teachers and his comrades, he is no longer an investigator alone with his problem; he takes his place as a speaker, between his problem and his hearers. There may be cases in which his personal experience deserves narration; but in scientific communications, personal items should, as a general rule, be relegated to the background; the speaker had best try to obliterate personal matters, which always give a more or less subjective flavor to a report, and strive to make himself simply the conduit through which the essence of his subject, in the most objective form, shall flow to the minds of his hearers. He has no longer abundant time, but is limited to half an hour, or an hour at the most; at the end of which time his audience ought to have acquired the gist of what has taken him weeks or months to learn. Evidently then the speaker must present only a selection of his best facts, theories and conclusions, in the most carefully planned order. He must say nothing at all about much of the material that he has gathered; he must touch very lightly and briefly on various subordinate items, and he must bring forward only those statements for fuller presentation which bear most significantly on his problem, and which can as far as possible be easily understood and remembered by his hearers. For this purpose he must, of course, before he begins to speak, know what grade of audience he is to address: for however useful the exercise of merely addressing an audience may be to an inexperienced speaker, whether what he says is understood or not, he must remember that an audience which has listened for half an hour or more and learned little, has wasted its time. A courteous consideration of those present, as well as a selfish regard for the opinion they will form of him and his work, should lead the speaker to make every effort to repay them for their time and attention, by making his presentation as intelligible and interesting as possible. He must therefore strive to produce a clear and definite understanding of his results in the mind of each hearer, in such form that a good share of them can be carried away and remembered. Hence it is not only on the ground of a generous consideration for the feelings of his audience, but, as above said, also from a selfish interest in his own progress, that he ought now to strive to make himself clearly intelligible. If he does not do this, he will be like an unsociable gold-washer, who, with patient endurance, has worked over a great volume of gravel for the sake of finding a few grains of gold, and who then, instead of having the gold refined and coined in form for current circulation among his fellows, keeps it in the comparatively useless form in which he found it; and at the same time complains that the value of his patient work is not recognized.

In view of all this it is manifestly desirable that a student should give due attention to the presentation of his results, as well as to the methods of investigation by which the results were gained. He will be aided in both these worthy efforts if he recognizes clearly the striking differences between the two processes, and then gives to each process the attention necessary to its best development. An analysis of the method of investigation, as applied to the study of land forms, here follows. A fuller statement regarding presentation will be given in a second article.

Analysis of Investigation.—As long as geography was concerned only with the observation and record of visible facts, its methods were relatively simple. They included, as far as land forms are concerned, the determination of latitude and longitude, the measurement of directions, distances and altitudes, and the preparation of maps of appropriate scales, along with an empirical description of the facts observed. For those geographers, however, who, in these modern days, enter whole-souled into the explanatory method of describing land forms, there is needed, in addition to all the earlier requirements—for every modern geographer ought to be well exercised in the preparation of empirical descriptions, as well as in the arts of surveying and cartography—a careful and conscious training in theoretical investigation; because every explanatory description, in so far as it introduces the supposed facts of the past as the best means of describing the visible facts of the present, goes beyond observation and employs theories; and theories can be successfully established only by the critical use of scientific methods of investigation.

The different mental processes involved in an investigation of the kind with which we are here concerned may be arranged as follows: observation and record of accessible facts; induction of generalizations; search for fuller explanation; invention of hypotheses or supposed mental counterparts of invisible facts; deduction of consequences from each of the invented hypotheses; confrontation of the consequences with appropriate facts; preliminary judgment; revision and improvement of each process; final judgment of the degree of correctness of various invented hypotheses.

Observation and Record of Accessible Facts.—The first step in a problem is the acquisition of a certain number of facts. This may involve original observation, as in the outdoor exploration of a geographical field, or it may be based on second-hand observation, as in the study of some other observer's records in books and maps. In either case, the investigator must be alert to avoid deception by mistaken appearances and by misleading subjective sensations; at the same time the mind must be kept sensitive to every real impression, to which it must respond in the most docile manner, submissively recognizing the facts as they stand, not constraining them in the least one way or the other. The investigator must be untiringly active in traversing his outdoor field, and omnivorous in devouring all pertinent material in the library. Indeed during the process of acquisition, outdoors and indoors, the investigator's mind must be like a fresh and sensitive photographic plate, on which no previous impressions blur the new ones that are made on it.

The facts mentally acquired must in some way, graphic or verbal, be recorded; and at the outset the records should be made in colorless empirical form, as free as possible from theoretical prepossessions. It will be chiefly in proportion to the larger or smaller measure of previously acquired experience that the observer will, at this early stage of his study, employ roundabout phrases or technical terms in recording the facts that he comes upon. If he says: "That is a promontory," this simple empirical statement implies that he sees a certain configuration of land and water, and recognizes that it possesses the essential features of a typical configuration already known from previous experience, for which the empirical term, promontory, has been adopted by general consent. But if he says: "That is a delta," the statement involves some measure of theory. It implies, as before, that he sees a certain number of features in the land form before him, and that he recognizes their correspondence with the essential features of the concept or type, for which the name, delta, has been agreed upon; but inasmuch as a delta is the product of a certain process acting under certain conditions through some unobservable period of past time, the observer has here made a leap into theory, although he may be hardly aware of it. As soon as such a leap is recognized, the visible features of the land form before the observer should be reexamined and stated for the time being in purely empirical terms; that is, in terms based on what is immediately seen, instead of in part on what is inferred. All this calls for fair-minded deliberation, the development of which demands time and training. If this cautious procedure seems slow and cumbersome, it should be practised with respect to various explanatory terms now commonly in use, such as delta, dune, volcano, moraine and so on, until it can be performed with ease and speed. During the progress of such training, a few examples of this elementary kind of analysis should be written out *in extenso* in the investigator's note book. The number of pages of careful records may at this time serve as a better measure of progress made by a young geographer than the number of miles traversed over hill and valley.

Induction of Generalizations.—When new facts are encountered they are, as has just been shown, more or less consciously compared, in the way of likeness or contrast, with acquisitions of previous experience. As progress is made, groups of similar facts are formed, the several members of a group being alike in respect to certain features that are therefore taken to be essential. An active-minded student quickly generalizes the repeated features by which all the observed members of a group are characterized; thus he conceives an idealized type; and at the same time relegates individual features to a lower rank. As new facts fall into groups already formed and give further warrant for the provisional generalizations previously made, a careful phrasing or formulation of the generalized features should be attempted, with some mention of the way in which individual examples depart from the idealized type. Thus an advancing investigation passes from the recognition of separate facts to the induction of generalized ideas. Certain classes of facts are so fully accessible to observation that the generalizations induced from accumulating records suffice to provide a reasonable understanding or explanation of the phenomena concerned; for example, the work of the wind in sweeping sand across a desert and whirling dust high into the air may be seen in operation; or the behavior of rivers in draining their basins and in transporting land waste may be closely studied by direct observation: hence wind action and river action may in these respects come to be understood by induction alone. But the larger action of these agents, as in the erosion of elaborate valley systems by rivers, and in the sculpture of peculiar desert forms by the winds, demand much unseen work in long past time; and even if induction on a widely extended basis could ultimately bring forth the full explanation of such problems, the mind is too impatient to wait for so long postponed a result, and seeks other means of reaching the same end.

Search for Theoretical Explanation.—One sometimes meets inductive investigators who say that they believe it best not to enter upon the speculative aspects of their work, even in complicated problems, until all the facts have been gathered; but such caution is unwise, even if it be mentally possible in one who is capable of conducting an original investigation. An unintelligent person may indeed see various outdoor facts, and continue to observe, collect and record them, and yet never ask himself or anyone else about their cause; but such a person is not mentally fitted to undertake the investigation of new problems, such as are here considered. On the other hand, when an earnest investigator comes upon facts of a complicated nature, he can not help wondering how they came to be what they are; he is not satisfied with the slow progress of induction toward their explanation; he inevitably feels some curiosity as to their invisible origin, that is, as to so much of their history as has already passed; he is discontent to remain ignorant; his mind is alert to find hidden meanings, just as his eyes are watchful to see visible features. He wishes to know about past facts which, in their time, were as veritable as are the facts of to-day, and which taken with to-day's facts assume that reasonable relation which we call explanation. This is precisely as it should be. If by good fortune the student's wonder and curiosity are so much aroused by what he sees, that they excite the invention of a possible explanation for his novel facts, the part of wisdom is surely not to turn his mind away from this invention, which may prove to be an extremely useful one, but merely to refuse immediate belief in it, before its value has been tested. The danger here lies not in the wish for explanation, nor in any ingenious invention of an explanation, but in the acceptance of such an invention as if it were the final truth. That is truly a serious error; an error that is not to be guarded against by stifling the inventive faculty, but, as will be shown below, by arousing the critical faculties to a rigorous examination of any suggestions that the inventive faculty may bring forth.

Invention of Hypotheses.—The search for explanation of observed facts may be made in some cases by the memory, which may recall an explanation previously learned. In physics and chemistry, the search for explanation is largely aided by experiment; but in the study of land forms experiment serves chiefly to illustrate explanations already reached, rather than to lead to new ones. We are here chiefly concerned with the kind of search which calls the investigator's own faculty of invention into play—the kind of search which tries to make a new combination of some pertinent facts or principles of previous acquisition with some of the facts of new observation, in the hope of thereby bringing about a clear understanding of all the facts under discussion.

The faculty of invention is peculiar in working to a large extent subconsciously. Facts to be explained can be intentionally observed; previously gained knowledge may for the most part be consciously reviewed; but the desired explanatory combination of old knowledge and new facts may not be immediately found while the conscious search for it is going on. Invention is, however, much favored by active observation, and spurred on by an eager spirit of inquiry; it is greatly aided by mental ingenuity, but it is seldom immediately accomplished by conscious intention. However, the faculty of invention can be cultivated if many facts, old and new, are frequently brought to conscious attention, and the wish for explanation and the search for it are often renewed. Then the subconscious mind will continue the search, and after an interval, during which the matter has been apparently out of mind, an explanation may most unexpectedly awaken attention by springing into consciousness.

The sudden birth of an apparently successful explanation is truly a most delightful experience; indeed so delightful and encouraging that many an investigator has mistaken it for the climax or crown of his work, and accepted it as the whole truth without further question. But, as has already been pointed out, the too-ready acceptance of an untested invention, as if it were true, is dangerous. The investigator must recognize that it is no great recommendation of an invention, that it explains the partial group of facts that it was made to explain. Of course it must do that; it would deserve no consideration at all if it did not. But in order to deserve acceptance as the true counterpart of past facts, it must do much more. It must explain various facts that it was not made to explain; facts that it did not expect to explain; facts that were not thought of, or were not even known at the time of invention, as will appear more fully below.

The investigator of course hopes that his invention, based on some of the observed facts, will prove to be the true counterpart of some past facts, or of some invisible principle or process, by means of which he shall gain a full explanation of all the observed facts; that is, an understanding of the manner in which they have been produced. While the invented counterpart remains of uncertain value, because untested, it is often called an hypothesis; and its uncertainty may be further indicated by calling it a provisional, or a working hypothesis. If later on, it survives all the tests that can be applied to it, it is then usually called a theory; or in order to emphasize its proved value, an established theory. But it is never, so far as the unseen facts of the past are concerned, anything more than the mental counterpart of those facts. Indeed, inasmuch as an hypothesis, when first invented, is usually based on only a few of the observed facts, it will then be only the counterpart of a few of the facts of the past, or of some general principle that suggests the genetic relation of partial groups of facts, past and present. Much more than the mere invention of such an hypothesis must be done before a complete explanation of all the facts is reached; and it is through the additional work, by which supplementary facts and fancies are correlated, that an invented hypothesis is tested.

As soon as the tentative nature of an hypothesis is understood and its possible failure is recognized, the investigator should realize that he must not stop inventing when his first hypothesis is brought forth; he must urge his subconscious mind to continue bringing forth inventions as actively and ingeniously as possible. He must thus equip himself with several rival working hypotheses,[2] to each of which he must give warm welcome and impartial friendship, but to none of which must he offer special protection or advocacy. The defence for a hypothesis is provided chiefly from new details that are added to it after its invention, or by new facts which are brought to light by its aid. If no defense of this kind is found, the hypothesis must be regarded as only a tentative speculation.

Deduction of the Consequences of an Hypothesis.—Before any decision as to the truth of a hypothesis is attempted, the question must be asked: What consequences must it have in addition to those facts which it was made to explain? An altogether new faculty is now called into play, the faculty of deduction, by which the consequences of a hypothesis are logically worked out. Here again experimentation is extremely useful in physics and chemistry, and it is coming to be more useful than it has been in biology and geology; but in the study of land forms experiment is at present rather imitative than demonstrative, and it will not be further considered here. What we have to examine now is a logical faculty that can be more consciously used than invention, but one which, unlike observation, can be carried

[2] T. C. Chamberlin, "The Method of Multiple Working Hypotheses," *Journ. Geol.*, V., 1897, 837–848.

on in the dark with the eyes shut. During the exercise of this faculty the investigator must in the most critical manner and with the aid of all necessary pertinent knowledge, think out or deduce everything that would happen, if an invented hypothesis were really true; and this he must do for each hypothesis in turn. The consequences appropriate to each hypothesis must be kept in groups by themselves; and these groups of hypothetical consequences must be carefully distinguished from the facts of observation.

In a geographical problem, the investigator must mentally search out, in view of each hypothesis that he has invented, the whole sequence of changes that would take place, the whole sequence of land forms that would be developed, if the class of forms with which he is dealing were followed all through its history, past, present and future. No invention should be hastily discarded, because it appears at first sight to be improbable; for such appearance may be more determined by the scientific fashion of the time, or by the mental habit of the investigator, than by anything inherent in the invention itself. Particular attention should be given to the deduction of unlike consequences of rival hypotheses; for, as will soon appear, it is particularly by means of these *instantiæ crucis* that successful and unsuccessful hypotheses are discriminated. Those who find deduction irksome should be advised to practise it until it becomes easy and agreeable; just as careless observers should be urged to continue observation until they can perform this fundamental process with accuracy and enjoyment. In no case should an investigator, particularly an unpractised investigator, put his trust in that rapid mental process called intuition, and hope by its uncertain aid to leap from invention to conviction. Let intuition be welcomed, just as invention is; but after it has leaped to its goal, its half-conscious path should be carefully retraced and the safety of its leap tested.

Confrontation of Consequences with Facts.—We now reach a stage in which the faculty of impartial comparison is brought into play. Facts have been gathered abundantly by the active observer, who is still at work gathering yet more of them; hypotheses have been brought forward in good number by the ingenious inventor, who is, however, still at work in the hope to find new ones; the consequenees of each hypothesis have been carefully worked out, group by group, by the patient and logical deducer, who stands ready to elaborate the consequences of new hypotheses as soon as they are found; and the consequences are now to be confronted, group after group, with the facts by the impartial comparer, in order to see how close an agreement they reach. This is as if the observer should marshal his battallion of facts in good order on one side of a parade ground, and the deducer should lead forth the battalions of consequences one after another and halt them opposite the marshalled facts, so that the comparer could to best advantage inspect the opposed arrays, with the intention of seeing how closely any battalion of consequences matches the battalion of facts. In making this inspection, the comparer must evidently give particular attention to the facts from which an invention did not spring; and look closely to see how successfully they are matched by the consequences of the invention. There must be no pressure to force an agreement where none exists; no constraining of the facts or torturing of the consequences to make them look like each other; but simply a fair-minded comparison, followed by a clear unbiased report as to where agreement and disagreement occur.

Preliminary Judgment.—If two rival hypotheses have yielded only identical consequences, all of which agree nicely with the corresponding facts, no decision in favor of either hypothesis can be made, and judgment must be suspended. The comparer must then ask the deducer if he can not find unlike consequences of the rival hypotheses; and if such are found close attention must be given to the degree of success with which they match the corresponding facts. Evidently, then, some consequences have a greater value than others in discriminating among rival hypotheses. If the consequences which are peculiar to one hypothesis match the appropriate facts, while the contrasted consequences of other hypotheses fail to do so, then a higher value may be given to this one of the several rival hypotheses, although before it had no greater value than its now defeated competitors.

Revision.—It will often happen, when confrontation is made and an encouraging amount of agreement is found between the consequences of a certain hypothesis and the corresponding facts of observation, that the agreement is nevertheless in some respects imperfect. It may be that, for some of the facts, no corresponding consequences have been deduced; or that, for certain deduced consequences, there are no corresponding facts. Then the investigator must revise his work. He must return to the stage of deduction, and look closely to see if those consequences which are only partly successful in meeting the facts, were rightly deduced; he must inquire if the absence of a certain consequence, with which some well ascertained fact ought to be matched, is perhaps due to oversight in his deduction. He must examine with particular care all the principles, introduced by memory from previous acquisition, to see if they are safely established and correctly applied; he must be especially careful not to overlook any tacit postulate, which, without being consciously recognized as such, has nevertheless been taken for granted without sufficient proof, and used as an essential basis for some of his deductions. He must go still farther back and modify his inventions in one way or another, in the hope that, after such modification, some one of them may lead to new consequences that will better than before fit the previously unmatched facts: hence it is important to regard each invented hypothesis as an elastic conception, whose form may be changed as necessity demands. The investigator must even return to his field of observation and reexamine the facts, particularly such as do not match with the well defined consequences of a partly successful hypothesis; and he must search his field with the sharpest scrutiny to see if any facts, previously unnoticed, really do occur in the manner indicated by unmatched consequences. In every way, the utmost care must be taken not to allow oneself to be satisfied with imperfect or incomplete agreements.

If these various recommendations are carefully carried out, the danger, often feared, that an investigator may, Procrustes-like, force the facts to fit the needs of a favorite hypothesis, is practically ruled out; for if the investigator has several unlike hypotheses in mind, and has deduced several unlike series of consequences from them, it will evidently be impossible for him to force his facts to agree with all of them, however much the facts may be trimmed or stretched.

Irregular Order of Procedure.—In practise the several processes that have been necessarily considered in systematic succession, are carried on in a much more irregular fashion. It has already been pointed out that invention may advisedly go hand in hand with observation. It is evident that, after a hypothesis has been invented, any time spared from observation may be devoted to deduction; and it often happens that the consequences of the hypothesis may grow to a greater number than that of the classes of observed facts then accumulated. Confrontation and comparison may be made repeatedly as observation advances, and revision is always in order the moment there seems to be occasion for it. The active-minded investigator, thus continually reviewing the different aspects of his problem, may gradually come to feel that one hypothesis, modified as far as needs be from its original form, appears to deserve greater acceptance than any of its rivals; then arises the great question: Is this hypothesis really true? Is it surely a correct counterpart of the invisible facts of the past? Clearly it is essential that an investigator, on reaching this stage in his work, should fully understand the nature of scientific proof.

Final Judgment.—It is at this advanced stage of an investigation that the exercise of a sound judgment is needed, in order to estimate the measure of confidence that may be given to an apparently successful hypothesis. The most important point to emphasize now is that, in such problems as we are here dealing with, the only available method of testing the truth of any hypothesis is to measure the agreement of its deduced consequences with the appropriate facts of observation. In this respect scientific proof is altogether unlike geometrical proof, in which the correctness of a theorem is never tested by its agreement with observable facts, but only by the continuity with which successively deduced steps lead forward from the postulated premises to the announced end. Geometry therefore corresponds—so far as a correspondence can be traced between a mathematical and an observational science—chiefly to that part of geological or geographical investigation which is concerned with invention and deduction; for these processes, like the similar processes in geometry, can be performed by mental reflection in the dark, and have no close dependence on observation.

In observational sciences it is necessary to examine critically the different degrees of agreement that may exist between the deduced consequences of an hypothesis and the facts gathered by observation, in order to pass a safe judgment on the value of the hypothesis from which the consequences were deduced. This return to the facts is one of the most important as well as one of the most characteristic elements of scientific work.

If observation has discovered but few classes of simple facts, and if invention has brought forth only one hypothesis, which leads only to a few simple consequences, the value of the hypothesis must remain in doubt, even if its consequences agree rather closely with the facts; because agreement in such a case may be a matter of chance. Here no decided opinion as to the value of the hypothesis should be expressed; judgment must be suspended, and the mind held open for further light, either from observation, invention or deduction. Again, if, as above pointed out, the groups of consequences deduced from two or more rival hypotheses are about equally successful in matching the facts, no judgment must be pronounced in favor of either, however strong the investigator's desire to reach a conclusion may be. But if the peculiar and numerous consequences of a certain hypothesis agree to a remarkable extent with the highly specialized groups of abundant and varied facts, such an hypothesis is strongly commended thereby, for the possibility of accidental agreement is greatly diminished as the facts and consequences to be matched become more complicated, and as the number of agreements increases. Furthermore, if the facts, as at first collected, seem of arbitrary occurrence and unrelated distribution, and yet are afterwards found, by the suggestive aid of an hypothesis and its deduced consequences, really to possess a previously unsuspected order and many previously unseen relationships, the hypothesis which leads to this larger and clearer view is thereby greatly recommended; for it is highly commendable to a theory, if it leads to the discovery of reasonable system where confusion seemed to prevail.

But we must go further; for it often happens that, after an hypothesis has been invented, and after its consequences have been successfully confronted with the previously observed facts, new classes of facts may be discovered for which deduction had provided no appropriate consequences. If an impartial revision of deduction then leads to the detection of new consequences which agree with the new facts, such added agreement greatly increases the probability of correctness adjudged on the previous agreement. More significant still is it, when certain peculiar or complicated consequences are deduced, for which no corresponding facts had been previously discovered, and when a return to the field of observation discovers facts of the peculiar character and in the significant situation assigned to them by deduction. This gives wonderful strength to the hypothesis from which consequences so prophetic can be derived: indeed, evidence of this is usually regarded as convincing, for the possibility of such a degree of accordance of consequence and fact being the work of chance is practically ruled out. Finally, if in the course of years, many investigators find many complicated facts in many parts of the world, all of which are successfully matched by the elaborate consequences of an hypothesis that was invented long before observation was so widely extended, the probability of correctness rises to so high an order that the truth of the hypothesis may be accepted, and it may be promoted to the rank of an established theory. The unseen facts that such a theory reveals are commonly accepted as of an equal degree of verity with the facts of direct observation.

The will or the wish of the sane investigator has no power to withhold belief, when this stage of theorizing is reached. And yet it can not be too carefully borne in mind that even if all the above requirements are satisfied, the most that can be said for the established theory is that its probability of correctness is so high that its chance of error may be disregarded. The fair-minded Playfair phrased this aspect of our problem admirably a hundred years ago in the case of river valleys:

> Every river appears to consist of a main trunk, fed from a variety of branches, each running in a valley proportioned to its size, and all of them together forming a system of vallies, communicating with one another, and having such a nice adjustment of their declivities, that none of them join the principal valley either on too high or too low a level; a circumstance which would be infinitely improbable if each of these vallies were not the work of the stream that flows in it.[3]

It is particularly in this matter of the increasing probability of correctness that the nature of geological or geographical proof is so unlike that of geometrical proof. There is never any talk of increasing the probable correctness of a geometrical theorem, when several different demonstrations are given for it. Each demonstration is absolutely correct alone, as far as anything can be absolute in the limited experience of our finite minds. But in our subject, it is always appropriate

[3] J. Playfair, "Illustrations of the Huttonian Theory of the Earth," Edinburgh, 1802, 102.

to speak of the increasing probability of correctness of a conclusion, even though general acceptance was given to it before.[4]

It is, furthermore, important to recognize that a fundamental but unprovable postulate underlies all this discussion; namely, that the present order of nature is persistent; that is, that time is continuous, and that physical forces have always conformed to the laws which now prevail. For however ingenious or amusing may be the speculations of the metaphysician as to another order of things—for example, as to a past condition of existence in which gravitation worked irregularly and variably, or as to a period of time when energy was created and matter was destroyed in haphazard order, or when time itself began or stopped—the scientist is not concerned with them, because they utterly transcend experience. All his discussions and conclusions as to the events of past time and the origin of the present features of the earth are of no avail, if his essential postulate of the persistence of the present order of nature is erroneous; but the frank recognition of this fundamental principle need disturb no earnest observer of the face of nature. Whatever doubts regarding the conclusions of science may be expressed by the ingenious metaphysician, with his fancied possibilities as to such inconceivable conditions as the beginning of time or the creation of matter; and whatever dissatisfaction may be expressed, regarding conclusions that are based merely on an unproved postulate and measured only in terms of high probability, by the absolutist who wishes to reach unconditional demonstration in all things, the scientist need not be disconcerted. He must still base all his work on the long accumulated and carefully tested results of thoughtful experience, for his work can have no other base; and he must accept as satisfying, even if not as absolutely certain in the absolutist sense, those high degrees of probability that are attained by well established theories, for there is no other satisfaction he can reach.

[4] "Bearing of Physiography on Uniformitarianism," *Bull. Geol. Soc. Amer.*, VII., 1896, 8–11.

PROFESSOR BROOKS'S PHILOSOPHY

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WHEN one examines the development of thought from the time of the early Greeks to the present, one finds that science and philosophy have in general ever kept pace in development and that their relation to each other has always been one of mutual and reciprocal suggestiveness. At certain times, of course, it has been the one, at other times, the other that has been dominant in its influence; but at the beginning, granting this to have occurred among the Greeks, neither was first, for both arose and for a considerable period developed together as an organic whole. The subsequent differentiation of problem and of method, although it can not be denied to have had its incipience in ancient thought, was in almost total abeyance up to the time of the Renascence, and is, of course, one of the distinguishing characteristics of modern thought. As a result of, or as identical with, this differentiation, we have to-day not only the great diversity of special sciences, but, as included in these, we have also bodies of systematic knowledge or "doctrines" which to many seem far removed from the practical and the factual. As good examples of such there may be cited the Hegelian philosophy, non-Euclidean geometry, the theory of assemblages, etc. However, not only do such bodies of knowledge or "doctrines" seem to be far removed from an empirical basis, but, more than this, they are often cited as standing in thorough-going opposition to the empirical sciences, and accordingly are frequently treated as pure speculations. To what extent this stigma is a merited one, I will not here discuss, but I shall be content to assert merely that an examination of their development shows clearly that these "doctrines," or whatever they may be called, have grown out of an earlier period of thought in which their progenitors were "near relatives" to the members of the distinctly empirical group. Accordingly, the influence of empiricism is not really lacking in them, but, rather, they are the products of the process of making explicit that which is at least held to be implied or involved in certain systems, philosophical and scientific, which are in direct contact with empirical problems and methods. Thus, as illustrating this and as forming a well-known and generally accepted instance of philosophical development, it may be said that Hegel goes back to Kant, Kant to Hume (in part), Hume to Berkeley, and Berkeley to Locke; and Locke worked out his philosophy, which concerned primarily the question of the "origin, extent and validity of knowledge," in thorough-going dependence on the mechanistic views and science of his time.

Although philosophy may at times, then, seem to get far away from contact with the empirical and the practical, still this may well be only a "seeming," and there may be and generally is a very genuine continuity of influence and of knowledge through the threads of that consistent and rigorous reasoning which forms the discovery of implications and presuppositions. But even a remoteness of this kind is not always the case. Far more frequently, indeed, has there been intimate contact and close relationship, if not within the mind of one man, then as within that larger whole which we call the *Zeitgeist,* whatever interpretation may be given to this.

As concerns scientists and philosophers, it must be admitted that all of them are educated and develop with that whole body of knowledge which the human race has won theoretically accessible to them. But specialized environment and congenital predisposition really limit this accessibility considerably, and together result in specialized interests and specific development. But this means only that from a great body of knowledge certain parts are selected and become revivified in the mind of some individual, to furnish the basis for further development, for originality, for discovery, for advance. Yet as this process occurs, it issues in a two-fold result. There is a certain unity in knowledge, not of that kind which means that any part is theoretically or *a priori* deducible from any other part, but in the sense that there are many parts or aspects of reality to be known, and that knowledge of them must form a logically consistent whole. Now education and training may result in a mind which is aware of all this, in a mind, therefore, which, although it is fully informed, and critical, and constructive in some special field, is also fully aware that this field is but a part of a larger whole and that through this relation special investigation gets its significance and importance. Such a mind may be said to be philosophic, or, if one prefers, scientific in the best sense of the term. On the other hand, intellectual development may result in a mind which is seemingly unaware, even ignorant of the history of the race, of its thought, of its hopes and aspirations, a mind which accordingly finds the *summum bonum* only in one line of thought and investigation, which ignores or even denies the relation of this to a larger whole, because it is ignorant of this whole, and which accordingly pursues its own way along the straight and narrow path of only highly specialized investigation. While one must not speak disparagingly of such minds, since the history of thought shows quite clearly that to these also are due very important contributions to knowledge, still of such a mind it must be admitted that it has the defects of its qualities, namely, that it is in danger of wasting its strength on that which is not significant, and that in studying, for example, the problem of life it frequently forgets both what life itself is as well as how to live.

It is very distinctly to the former type of mind that Professor Brooks belonged; for, keen-sighted pioneer and influential biologist that he was, he was also in thorough sympathy with life and the living in all of their aspects, past, present and future, emotional, intellectual and religious. Perhaps for that reason, too, he was the great teacher and the inspirer of men that with one acclaim he is acknowledged to have been. Technical philosopher he was not, sophisticated philosopher he was not, but sympathetic philosopher he was, and in this respect, since he was biologist also, he was unusual. Contributions to philosophy, also, he did not make, but rather, conversely, he let philosophy make contributions to him, and in this he was again unusual. And yet all the time he was on the lookout in the various fields and aspects of biological science for that which was of genuine significance, for that which had a bearing on some of those great questions whose solution is of paramount interest and importance and which, therefore, are eternal questions.

These statements concerning Professor Brooks will be made more convincing by considering some of the typical instances in which he brings philosophy and science together. In fact, it is only such *instances* that can be cited; for of system, either in philosophy or biology, Professor Brooks was quite innocent. Significant and typical of the general attitude which he took, and forming indeed a discussion of one of the most salient problems in biology, physics and philosophy, are the data, the arguments, etc., advanced in Lecture II., entitled "Huxley and the Problem of the Naturalist," in The Foundations of Zoology. Here Professor Brooks cites in particular Huxley's statement: "If the properties of water may be properly said to result from the nature and disposition of its component molecules, I can find no intelligible ground for refusing to say that the properties of protoplasm result from the nature and disposition of its molecules," and follows this with comments which amount to his taking this position: Huxley's statement can be granted to be valid, but, so granting it, it does not mean that there is or ever can be the possibility of an *a priori* deduction of the properties of protoplasm from those of its constituents, but that the connection between these must be bridged by induction. For the properties of protoplasm, or indeed those of the organism at any level are not the additive result of those of the parts, but contain something quite new. Thus Professor Brooks indicates the limitations of the mechanistic view of life, limitations which, however, are found as well in the inorganic realm, and which, therefore, demand that in applying theoretical mechanics to nature, either inorganic or organic, an appeal must always be made to experimentally obtained fact in order to discover those constants which are actually found and used in the equations of applied mechanics (*vide* the gravitational constant). It is the failure to make this distinction between theoretical and applied mechanics, with a resulting misinterpretation on both sides, that has conditioned psychologically the tenets of those two schools, namely, the vitalistic and the mechanistic, between which there has been so much discussion of recent years. In his attitude toward mechanism the adherent of each school has in mind a different thing, with the consequence that there is no genuine joining of issue so far as the fundamental problem is concerned, while there may be and, I think, really is a genuine agreement in regard to it. Thus, in opposing the view that the organism is a mechanism, the vitalist tacitly means that it is not a mechanism in the sense of pure, theoretical mechanics, *i. e.,* of the "geometry of motion," as a deductive system; and in this he is right. But he really also always admits, at least tacitly, that the organism *is* a mechanism in the second sense, *i. e.,* that, although it has properties which can not be deduced from those of its parts, the former nevertheless result from or are determined by the latter.[1] On the other hand, the mechanist, in opposing vitalism, first fails to make clear that his own position is that the organism is a mechanism in the second sense, and, secondly, wrongly considers the vitalist to be opposing this second view, whereas he is really opposing only the first, the purely theoretical, deductive, mechanistic position.

This solution of the problem is, in fact, recognized by Professor Brooks, and the development of its consequences forms the chief part of his philosophical position, as will be seen subsequently, but it is a solution which, as demanding that the actual properties of nature at any level of synthesis must be found by observation and experiment, both allows that the organic realm has certain properties which the inorganic world has not, and yet that these should be interpreted and treated mechanistically in the second sense. Most intimately connected with this whole question are a number of other philosophical considerations to which Professor Brooks gives much attention. It is from these that he arrives at that which is really his ultimate philosophical position, although, it must be admitted, this is not a very complex or sophisticated one. For Professor Brooks, although he cites and quotes from such sophisticated thinkers as, *e. g.,* Plato, Berkeley and Kant, is predominantly (he is not always consistent) a realist, first "naïve," and then "critical." Thus, although he dedicates his "Foundations" to Berkeley, and quotes him oftener than any other philosopher, he never seems quite to grasp this philosopher's subjective idealism. And

[1] Cf. Driesch in various places in such volumes as "Naturbegriffe und Natururteile" and "The Science and Philosophy of the Organism."

as with Berkeley, so with the others; for example, he never quite gets hold of Kant's phenomenalism. It is Hume, however, who, through that analysis of causation which made him famous and which constitutes the basis for the logic of induction, is of dominant influence on Professor Brooks. The results which Hume obtained are, as is generally well known: (1) that, tracing our concept of cause back to its origin in perception, there is given here only sequential and factual but never necessary connection; (2) that, however, from the experience of frequently repeated specific sequences, a belief in their regular and uniform and even necessary occurrence is generated, or, more generally, that a belief in a universal, necessary order is formed. (3) The belief is justified and is of value *practically*, but nevertheless, that there is a universal and necessary regularity or order is a pure assumption, or (Mill) it is itself that generalization, by induction from a limited number of cases, which lies at the basis of all specific inductions and gives the "inductive syllogism." All this means that, although a purely deductive theoretical mechanics as = "the geometry of motion" is possible and as such may be identified with determinism, this can be applied to nature only by finding the numerical values for certain functions or properties or qualities *experimentally and factually*. It means, accordingly, that in just this respect nature is not deductive, is not determined, and that the view that it is "order" is an assumption neither proved nor provable. This does not mean that the same cause under the same conditions does not bring about the same effect; it may, or it may not, but that this *is* the case is simply the same assumption over again.

It is on the basis of this criticism and analysis of causation, of "order," etc., that Professor Brooks discusses very interestingly such topics as the "Philosophy of Evolution," "Paley and the Argument from Contrivance," "The Mechanism of Nature," etc. If mechanism is to be equated with determinism and "order"—and that is all that it really means to the majority of biologists as well as to the majority of people—then it also is, like them, as above explained, only a pure assumption. But the possibilities or consequences resulting from this are interesting and important. For, with it unproved that there is that kind of continuity and causation and "order" and determinism which would make a purely deductive knowledge possible, there is the logically valid opportunity for spontaneity and genuine discontinuous origin and freedom and teleology and purpose; and yet all of these are quite consistent with that other view of "order," etc., which means that, when specific instances of these have once been discovered by induction, the presumption and the probability is that under the same conditions they will recur. But this simply means that there is a genuine evolution and advance which is at once compatible with mechanism in the above second sense of the term and which yet, as made up of the appearance of new existents, is itself irreducible to continuity, and is uneliminable.

But it is in substance just this view which Professor Brooks accepts and defends in one way or another in a number of Lectures of the Foundations. In order to carry confirmation to the reader's mind that this is the case a few typical passages may be quoted. Thus we find Professor Brooks saying: "So far as I can see, the reduction of all nature to mechanical principles would mean nothing more than that all phenomena of nature are orderly."[2] "When we say nature is orderly, we mean each event may be a sign which leads us to expect other events with confidence."[3] "When, as commonly happens, we change *will* into *must,* we introduce an idea of necessity which most assuredly does not lie in the observed facts."[4] Of peculiar interest, since, in perfect agreement with Professor Brooks's general view as above expounded, it reveals his position as to the relation of mind and matter, is the statement that "if such a discovery (*i. e.,* that these two worlds are different aspects of one and the same world reduced to mechanical principles) should ever be made . . . I can not see how it could possibly show that mind is anything but mind."[5] Briefly, this means that if consciousness were found to be, for example, energy, it would be that kind of energy which would have just those properties which consciousness is found empirically to have. Professor Brooks would then bring mind itself within nature, *i. e.,* he would treat it, like other things, quite empirically, and this, I think, is the correct position. But it is a position which has interesting consequences! For, on the one hand, let his interpretation of causation and "order," etc., be remembered. Now Professor Brooks holds that this same interpretation applies also to mental events; the "order," causation, etc., here are factual only to the limited extent actually observed; beyond that they are assumptions. But what is it that makes the assumptions? Why the mind itself, which either is, by the *same interpretation,* simply the series of mental events, *or,* if not this, is something more. In the former case we have, then, that which is assumed "order," namely, mind, assuming "order" elsewhere, and so on again and again. Consistency demands, then, that it be admitted that that which may be indeterminate, namely, nature, is known by that which is also indeterminate, namely, mind! But the consistency is itself an element in this latter indeterminateness. The situation thus resulting is, of course, a perplexing one; for, to look at it from a slightly different angle, it means that Professor Brooks as evolutionist makes mind and life, with their assumed "order," etc.,

[2] Foundations, p. 289.
[3] *Ibid.,* p. 305.
[4] *Ibid.,* p. 294.
[5] *Ibid.,* p. 308.

develop in response to the "order" of nature;[6] but this response is itself only another term for causation, and must, in order to ensure consistency, itself be interpreted like other cases of causation. But this means that everything is brought within a causal "order" which is held to be only assumed but not proved or provable. And yet it would seem that the very attempt to *ground* this general view presupposes the contradictory position, namely, that there is a causation, a necessary connection, a unique determination and "order," which are more than assumed. That there is this causation is, however, a view quite compatible with the discontinuity view previously advanced.

Professor Brooks is seemingly not aware of this last possible supplementation of his view, but yet he says nothing which would contradict it. By it the causal connection, discontinuous though it be at certain points, the "order," etc., *are more* than assumed; although assumptions may be made about them, *they* are factual.

In accordance, now, with this whole general position, Professor Brooks (rightly) finds freedom quite possible logically because, as a fact, it is quite compatible with "order," and does not mean disorder, nor yet ultimate necessity. "We know we are free to do as we like; and we also know there are reasons why we like to do as we do." Briefly "The reduction of all the phenomena of life to mechanical principles would show that our likings and dislikings are what they might have been expected to be," and "would not disprove the reality or the value of any one thing we discover in our nature."[7]

Quite in line with all this is also the "immanent teleology" which Professor Brooks accepts and which may be made clear by a quotation both apt and amusing: "He who admits that cats are part of nature, and that skill in catching mice is important to the race of cats, must admit that nature is, so far, useful to itself."[8] Thus the teleology falls within the "order" of nature, is quite compatible with it, and indeed applies to a special group of phenomena within this (assumed) causal order. Either description may be made and both are correct.

Concerning the other philosophical aspects of Professor Brooks's writings much need not and indeed can not be said. To be sure, all through the Foundations he is continually quoting from some philosopher, or is raising some philosophical problem, but further than this he does not go. He does not contribute very much at least to the solution of these problems, but, rather, chooses certain statements and points of view of the philosophers as contributing to his own views. But he thus at all times reveals the heartiest sympathy for the results of the philosopher's reflections. "Whether it is desirable to place a prohibi-

[6] For example, in the chapter on "The Mechanism of Nature."

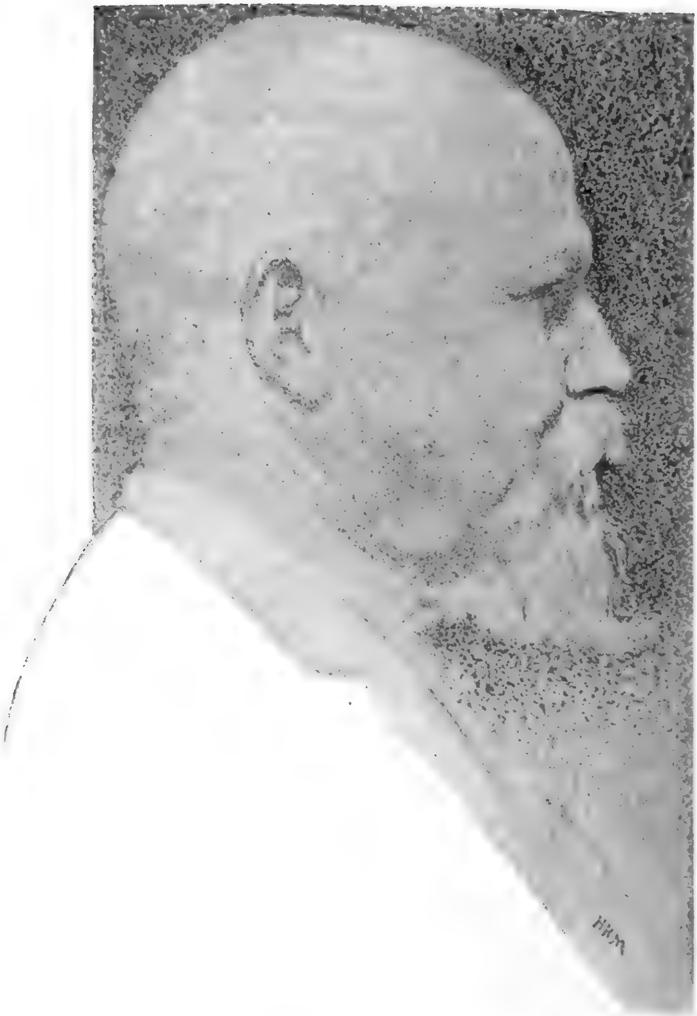
[7] Foundations, pp. 310–12.

[8] *Ibid.*, p. 305.

tory duty upon philosophical speculations or not, it is utterly impossible to prevent the importation of them into the mind," he says, and further raises the question if it is "not a little curious to observe that those who most loudly profess to abstain from such commodities are, all the while, unconscious consumers, on a great scale, of one or another of their disguises or adulterations?"[9] In this spirit he recognizes that such philosophical problems as those of "knowledge" and "consciousness," of the "principles of science" in general, of cosmology, and, more specifically, of psychology and ethics, are problems which must be solved in order to make the scheme of knowledge complete. What he does not recognize clearly, or at least does not develop, is the fact that, whereas the greater part of biology is consistent with any one of a number of philosophical systems, it is through evolution that a particularly strong leverage is secured by which it can be shown, perhaps, that only one point of view, namely, evolutionary realism, is the correct position; but just how this is the case I can not here demonstrate.

Some of the specific problems above mentioned are indeed discussed by Professor Brooks in some detail, but not very satisfactorily. A few lectures are almost purely biological, with only now and then a philosophical reference, but in general it may be said that, even including these, Professor Brooks is philosophizing all through the Foundations as well as in his other writings, and that in this characteristic rests his unusualness as a biologist. For while, of course, it must be admitted as a well-known fact that his philosophical interest did not lead him to give up the exact observational investigation of detailed problems, one must go further, I think, and say that it was this same interest also that actuated and stimulated him in all such investigations by placing him ever on the lookout for the significant and important task. But yet at the same time he did not ally himself with any specific and definite constructive metaphysical system, not even with that of Berkeley. In fact, it may be said that with the real inner meaning of the majority of the great historical systems Professor Brooks seems to have been unacquainted. It is, rather, by virtue of his openness of mind, of his search for significant problems, and of his motivation by the spirit of philosophical investigation and criticism, that he not only allies himself with philosophy, but was himself a philosopher, and in all this he furnishes an example most worthy of imitation, if not of emulation, by the investigator in any special field of scientific research.

[9] Foundations, p. 25.



Alpheus Hyatt

ALPHEUS HYATT, 1838–1902

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ALPHEUS HYATT, junior, was born in Washington, D. C., on April 5, 1838.

Late in the seventeenth century, the ancestors of Alpheus Hyatt moved northward from Virginia into the young colony of Maryland, where they soon became large landed proprietors and raisers of tobacco; the colonial manor of Tewkesbury on the Potomac River being owned by Charles Hyatt, Esqr., the great-grandfather of Alpheus Hyatt, senior. Hyattsville was also the seat of certain of Alpheus Hyatt's ancestors.

Alpheus Hyatt's father was a leading merchant of Baltimore, and in common with many men of affairs in southern cities, he made his home in the country; each day driving in to his counting-house in the city. The old Hyatt home was "Wansbeck," a colonial mansion shaded by great oak trees and placed upon the summit of a hill far from the city's dust and turmoil. It still stands to-day, but is now in the heart of the city at the corner of Franklin and Schroeder Streets, where it serves as the Child's Nursery and Hospital of Baltimore.

Here among the woods and fields of "Wansbeck" young Hyatt began his studies in natural history, becoming an ardent collector of insects and aquatic life; a pursuit which brought him into intimate comradeship with young Alfred Marshall Mayer, a boy of nearly his own age. The friendship between the little naturalists lasted through life, although Hyatt, true to his early inclination, remained constantly a student of animal life, while Mayer eventually became a physicist. Hyatt's interest in paleontology was first awakened by the sight of a collection of minerals and fossils possessed by one of his early teachers, Captain Allen, a retired army officer.

Although none of Hyatt's ancestors had been distinguished for remarkable mental characteristics, and none had sought intellectual or even professional careers, his mother was a woman of strong and decided character and an amateur artist of considerable ability, some of her copies of old masters and tapestries being noteworthy. The abundant means possessed by his father afforded him every educational advantage of the day, and his early education was commenced under private tutors, but soon he was sent to the Military Academy of Oxford, Maryland, to be prepared for Yale University, which he entered as a freshman in 1856.

"WANSBECK" AS IT IS TO-DAY.

It may be of interest to observe that upon his arrival in New Haven his father presented his name to various tradesmen of the city, directing them to supply his son's demands upon them, and as these included the opportunity to order all that livery stables or wine cellars could provide, it is greatly to young Hyatt's credit that he was a sober, serious-minded, hard-working student from the moment of his arrival in New Haven.

He remained only one year at Yale, and then his mother withdrew him from college and took him to Italy, where he came under the influence of certain catholic friends of the family who sought to convert him to the service of the church. In his journal he gives a graphic description of the magnificence of the papal court, but is distressed that "the Swiss guards in their harlequin uniforms stand fencing off the high altar from the approach of common people." He might still have acceded to the counsels of his mother's catholic friends had he not one day seen the pope's dragoons charge wantonly and without warning upon a crowd of merrymakers on the Corso, crushing four of them to death. The horror of this scene, and the filth and misgovernment of Rome under Pius IX., turned him with loathing from all thought of serving such a heartless régime as that of the papacy of those days, and in his journal he exclaims:

> How much do I love my own country after witnessing that disgraceful scene on the Corso. How I prize her free, glorious institutions where a man's life, will and speech are his own and not the property of emperor, king, or potentate. God bless my native land and preserve her as a living light to these poor down-trodden, though fine people.

He was but nineteen years of age, yet he had now determined to devote his life to science.

In 1858 he returned to America and entered the Lawrence Scientific School of Harvard University, studying engineering, but the great Louis Agassiz, always seeking promising young pupils to instruct, soon discovered Hyatt and drew him into his own laboratory of natural history, where in an inspiring atmosphere of research and study he was to form close and life-long friendships with his fellow students Clarke, Morse, Packard, Putnam, Scudder, Shaler, and Verrill. With them in 1860 he formed the Agassiz Society which met at frequent intervals to discuss zoological questions, Professor Agassiz himself attending the meetings, and in the summer of 1861 with Shaler and Verrill as companions he went to Anticosti Island in the Gulf or St. Lawrence, collecting fossils and marine animals.

Louis Agassiz's lucid exposition of von Baer's law and his own additions thereto, and his high praise of the philosophy of Oken, produced a profound effect upon young Hyatt's mind, and he is said to have learned Agassiz's " Essay on Classification " by heart. One of the most graphic of Louis Agassiz's lectures was upon the coiling and final uncoiling of the shells of fossil ammonoids in which he compared the twisted forms found in the Cretaceous just before the extinction of the group, to the writhing contortions of a death struggle. Listening to this lecture, Hyatt became so inspired that he determined then and there to devote

Professor Hyatt's Desk, as it was when he left it on the day of his death.

his life to the study of these fossils. It can not be said, however, that he was entirely moulded by Agassiz, for Hyatt was a fearless and independent thinker, and though modest in the expounding of his views, he nevertheless clung tenaciously to his own opinions.

Few men of science have been so free from egotism as was he. He was a kind friend to many a young student of Harvard, for he never seemed to lose his contact with youthful thought, and delighted to receive instruction from old and young and every one great or small around him. In his address before the Agassiz Association in Mechanics Hall in Boston he tells of this, and unwittingly gives us a charming picture of his own generous mind and kindly heart. He was speaking of things the association might do to disseminate an understanding of natural history, and told of his friendship with an old farmer who had formed some geological theories of his own and who knew Professor Hyatt simply as "the man as studies rocks." Hyatt says:

> The wonder and delight in his old, wrinkled, weather-beaten face on finding that his ideas were not merely local, but universally true, and what he had thought out was not ridiculed but regarded with respect was a sight I have never forgotten.

He concluded this address by saying:

> The minerals, the rocks, the plants, the animals, the earth, the planets and the stars are full of facts unknown as yet to us. These are nature's books, the volumes are everywhere and no one is so poor that he can not have access to them—these are the books of the future, and eventually we shall have them collected in museums and issued as printed volumes now are for the instruction of the people.

In 1862 Hyatt graduated from Harvard with the degree of B.S., his scholarly standing being higher than that of any of Agassiz's pupils who had until then obtained this degree.

His inclinations were all for science, but the civil war had broken out and he felt it his duty to serve in the Union Army. His mother he succeeded in persuading into an acceptance of his views, but it was far otherwise with the remaining members of his family, from whom he became estranged only to be reunited after years of silence. He aided in raising a militia company in Cambridge and enlisted as a private, but was almost immediately commissioned a lieutenant and afterwards promoted to be a captain of the 47th Massachusetts regiment. For a time he was stationed upon Cape Cod and afterwards ordered to New Orleans, where he served as aide-de-camp on General Emory's staff.

I have a letter of this period written by the late Professor N. S. Shaler to their mutual friend, George H. Emerson, in which he says:

> So Hyatt has gone into the smoke of the great battle. May God defend him and grant him immunity from the fate of so many of our brave. He will win success and will make at once a good follower and an equally good leader.

The war being over, he was honorably discharged, and returned to Cambridge in 1865 to continue his studies. Louis Agassiz at once placed him in charge of the fossil cephalopods and this collection remained under his care until his death in 1902.

In 1865 he published his first scientific paper, a short one of only five pages in which he states that the Beatricidæ which he collected at Anticosti in 1861 are not fossil plants as others had supposed, but cephalopods. We know, however, that he was himself mistaken, for they are now believed to be hydrocorallines.

In the same year he wrote an appreciative notice of the life of his young college chum, George H. Emerson, a chemist of great promise, whose untimely death from overwork had terminated at its very beginning a useful life in science. While in college together Emerson and Hyatt had begun the critical study of the bible, Hyatt coming to entertain liberal views while Emerson became a ritualist. It was characteristic of Hyatt to disagree upon essential matters with his closest friends and yet never in any sense to lessen the mutual esteem and affection between him and them. His simple honesty, freedom from conceit and above all his cordial and generous nature made this possible. Thus it was that within a year of the time when he began his studies under Agassiz he became an evolutionist and an admirer of Lamarck, whom Agassiz characterized as "an absurd egotist." Independent of the theoretical side of his work Hyatt will be remembered as a great teacher and a leader in systematic zoology, for he was an uncommonly accurate observer and his publications present a vast body of well-founded facts.

The year 1865 saw Louis Agassiz's pupils, whom the war had scattered, again working by their master's side at Harvard. But the old relation of master and pupil could not long endure, for the truth was that the time had come for the young birds to fly from the paternal nest, and in 1867 Morse, Packard, Putnam and Hyatt severed their relations with Agassiz and cast in their lot with the Essex Institute of Salem; this movement being known as the "Salem secession." Salem thus became an active center in the natural sciences and so much public interest was awakened that in 1869 these four young men cooperated with a number of progressive citizens of the town to found the Peabody Academy of Sciences, and with the aid of Scudder and others they succeeded in establishing the first permanent American journal devoted to the natural sciences, *The American Naturalist,* Hyatt being one of its editors from 1868 to 1871.

On January 7, 1867, he married Miss Audella Beebe, daughter of Smith M. Beebe, Esq., of Kinderhook, N. Y.

During the period of his residence in Salem, Hyatt continued to study and to describe the fossil cephalopods of the Museum of Comparative Zoology at Harvard. Suess and Hyatt were indeed the first zoologists to attempt to distinguish genera and species among the ammonites, and Hyatt was the first to announce the fact that these fossils constitute a great group of the animal kingdom probably equivalent to a suborder. In 1867 he named 26 genera and 126 species of ammonites.

He also made a detailed and very careful study of the anatomy of the so-called "moss-animals," or fresh-water Polyzoa, the structural details of the species being tabulated in order to facilitate comparisons. This work was published in the *Proceedings of the Essex Institute,* in 1866–67, and also in the *American Naturalist,* and is illustrated by careful and accurate outline figures drawn from life by Hyatt and beautifully engraved on wood by that matchless draughtsman E. S. Morse. In this and all of his subsequent papers Hyatt furnishes a model that systematic zoologists will do well to follow in the accurate and detailed description of species.

While at Salem he also began that study of sponges which was to make him the leading authority among systematic zoologists of America upon these animals. His principal papers upon sponges were not published, however, until 1875–78 in the *Proceedings* and *Memoirs of Boston Society of Natural History.* He agrees with MacAllister that sponges constitute a subkingdom or branch of the animal kingdom equivalent to one of the larger divisions. He describes 36 new species, and gives an excellent account of the methods of the commercial sponge fisheries of Florida, and discourses upon the embryology, anatomy, physiology and relationships of sponges, deciding, in common with Barrois, that in sponges there is no gastrula stage.

But Salem was too small to provide careers for so many young, active and well-trained students of natural history. Of the four friends, Morse remained in Salem; Packard went to Brown University; Putnam became an anthropologist and curator of the Peabody Museum in Cambridge and also in other institutions; and on May 4, 1870, Hyatt was elected custodian of the Boston Society of Natural History. In 1881 he became its curator and remained the scientific head of the society until his death in 1902.

After 1873 he made his home in Cambridge, where he could be near the great collection of cephalopods of the Museum of Comparative Zoology, and in 1879, under the auspices of the Woman's Educational Association of Boston, he established a summer laboratory for the study of marine zoology upon his country place at Annisquam, Mass. At this time also he owned a 60-foot schooner yacht, the *Arethusa,* with which he made scientific cruises along the New England coast, going as far north during the summer of 1885 as the west coast of Newfoundland and lower Labrador, to study the fossils and the general geology of these regions. His companions upon this cruise were five young men, among whom were Professor George Barton and the late Dr. E. A. Gardiner.

The situation of Annisquam was found to be unfavorable for the site of a general marine laboratory, nor was Hyatt sufficiently interested in the minutiæ of executive detail to make a good director of a permanent station, so after a few years the Annisquam project was abandoned and the laboratory was removed to Woods Hole, Hyatt being the first president of its board of trustees.

Hyatt was a great, generous-minded, altruistic man; who formed warm and enduring friendships with those about him. He was a teacher and a student rather than an executive, and his faith in young men was one of the beautiful sides of his character. Advocates of peculiar theories of their own making are commonly conceited or narrow-minded men, but Hyatt was the reverse of this, for his modesty was real, and his breadth of view, founded as it was in superior knowledge of science, and in interest and respect for those about him, was constantly expanding. No man could have been more approachable, and no educator of his generation was more highly esteemed for his kindly personal qualities than was Alpheus Hyatt.

His interests in educational affairs in Boston caused him to be appointed professor of zoölogy and paleontology in the Massachusetts Institute of Technology, a chair which he held for eighteen years. He was also professor of biology and zoology in the Boston University from 1877 until his death in 1902.

But it is as a teacher of teachers that he will be best remembered by the public of Boston. He loved to teach, but was never a pedant, for as he says:

> Teacher and scholars should recognize that science is infinite, and they should work as companions learning from each other's observations. Better a child should learn to handle one animal, to see and know its structure and how it lives and moves, than to go through the whole animal kingdom with the best teacher.

His knowledge of invertebrate zoology was profound and extensive, and he had an apt manner in illustration which made his lectures popular and brought his pupils close to nature; as Agassiz said of him, "he possessed the essential element with which to engage the attention of an audience—knowledge thoroughly his own." In 1870 with support from Mr. John C. Cummings and the cooperation of many educational leaders and philanthropists, he organized the Teacher's School of Science and gave courses of lectures upon biology to the public school teachers of Boston. Between 1870 and 1902 more than 1,200 school teachers attended these lectures, and the school is still being successfully conducted by Professor George Barton. A good account of the origin and history of this school is given by Frances Zirngiebel in POPULAR SCIENCE MONTHLY, August and September, 1899.

Professor Goodale suggested that guide-books of a peculiar character should be written for the benefit of the teachers who might attend these lecture courses; accordingly, between 1878 and 1896, thirteen short guide-books designed to meet the requirements of the school were published, the authors being Mrs. Agassiz, Dr. H. P. Bowditch, Professor George L. Goodale, H. L. Clapp, Ellen H. Richards, W. O. Crosby, Hyatt, and Hyatt and Arms. Five of these pamphlets are by Hyatt; their titles are "About Pebbles," "Commercial and other Sponges," "Common Hydroids, Corals and Echinoderms," "The Oyster, Clam and other Common Mollusks," and "Worms and Crustacea"; and in 1890 he published in collaboration with Miss Jennie M. Arms (now Mrs. Sheldon) a remarkably clear, concise and well-worded book upon insects. This is the most elaborate guide-book of its series, and no work could give a clearer idea of the distinctive characters of the sixteen orders of insects classified in accordance with Brauer's scheme from the lowly organized Thysanura to the highly specialized Diptera. As a school-teacher's guide it is unsurpassed, and its clear explanations are admirably supplemented by 223 outline figures of common American insects. It is far more than an anatomical treatise, however, for it presents charmingly worded accounts of the development, physiology, habits and ancestry of the various orders of insects. Yet it is not a theoretical treatise, but aims to present to the teachers well-established and incontrovertible facts. Indeed, the authors take pains to advise teachers to avoid presenting mere theories to immature minds.

This association with the teachers in which Hyatt was so deeply interested won high appreciation from the intelligent public of Boston, a concrete manifestation of which appeared after his death in the founding by general subscription of an endowment known as the Hyatt Memorial Fund, the income from which is used annually to transport school children from the city into the country in order that they may be taught to observe nature in the field.

Altogether Hyatt's best work, apart from his researches, was that among the school-teachers of Boston.

Mrs. Jennie Arms Sheldon, than whom none is better prepared to speak, states that "as a museum curator Hyatt never lost interest in the larger plan or 'scheme' which his comprehensive mind had worked out for the arrangement of the material at his command. His 'natural classification' claimed much of his time and thought, and he sought to find assistants who could carry out the details which, naturally, did not interest a mind like his." His plan was that the museum should be so arranged that the visitor on entering should pass from the simple and more generalized groups to those more specialized. He possessed considerable mechanical skill, and delighted in hours of recreation to work as a carpenter and machinist upon his country place at Annisquam, and his invention, the "Hyatt bracket," has proved useful not only in museums but elsewhere.

At first sight, it must seem strange that so able, inspiring and lovable a teacher as Hyatt should have left so few disciples of his school of research, but it must be remembered that he enjoyed no opportunity to teach the young men who were pursuing the higher courses in zoology at Harvard. Through an unfortunate arrangement those who had charge of the various collections in the Museum of Comparative Zoology were not encouraged to give lectures to students, and they worked on throughout the years, their voices silenced, yet with active young minds eager to listen and to learn always near them. Moreover, the spirit of the department of zoology at Harvard during Hyatt's life-time was dominated by Weismannism, and Hyatt's views were thus in disfavor. Upon the rare occasions of his lectures he felt obliged to present not facts—the foundation-stones of his theories—but the theories themselves. Thus the impression grew up that Hyatt was a dreamer and that his theories were based upon erroneous or meager observations. Nothing could have been farther from the truth, for I have myself been surprised, in reading over his publications, to discover that his writings are crowded with accurate observations of indisputable fact, and even if the future should demonstrate that his theoretical deductions are wholly false, he will still be remembered as a great and accurate observer of nature. Concerning the truth or falsity of his so-called acceleration or "old age theory" we are obliged to admit that it has never been disproved even if it be not yet accepted as true. Hyatt's fate may be that of Lamarck and of many another theorizer: Appreciation and respect for his views must come only years after his death.

I will endeavor to give a simple explanation of his theories of evolution, avoiding the complex technical terms which he employed. He believed that the race, like the individual, has only a limited store of vitality and that both must develop, progress, decline and die in obedience to one and the same law. Thus the growth-stages of the individual actually resemble the stages in the evolution of the race to which it belongs; as he puts it, "the cycle of ontogeny is an individual expression and abbreviated recapitulation of the cycle that occurs in the phylogeny of the same stock." "Phylogeny, like ontogeny, is first progressive and thus attains an acme of progress. This acme is followed, however, by a stage of retrogression ending in extinction."

Hyatt derived his ideas of evolution from a study of the fossil nautiloids and ammonoids, those beautiful chambered shells which appear in the Cambrian; and the ammonoid branch of which becomes extinct in the Cretaceous, while to-day the half-dozen species of *Nautilus* are all that remain of the nautiloids. He was an ardent student of these fossils, and of the 103 titles in the list of his papers, 38 are upon these shells. He proved that the ammonoids are descended from the nautiloids, for he discovered that the protoconch or primitive shell of the nautiloids is soft and composed of flexible conchiolin so that it is usually lost after the chambered shell grows out from it, but in the ammonoids the protoconch is hard and calcareous and is always found at the narrow end of the series of chambers composing the shell.

The undisputed facts are that in Silurian times straight conical shells with smooth outer surface were common, and coiled shells were rare. In the Carboniferous the coiled shells gain in number and nodules, ribs or keels begin to develop upon their outer surfaces. In the Jurassic we find only close-coiled, or uncoiling shells, and those that uncoil tend to become straight with smooth surfaces, as were their ancestors long ago in Silurian times. The ammonoids arose as coiled forms from the nautiloids in Cambrian times, but in the Jurassic and Cretaceous they uncoil and thus resemble their straight-shelled nautiloid ancestors, the oldest of their race. Uhlig, Neumayr, Zittel, Hyatt and all other students of the group agree upon these points, and indeed Hyatt's observations of *fact* have won high respect for both their accuracy and their number. It is only in matters of *inference* that he is at variance with many zoologists.

Hyatt found that in the very young ammonoids the shell is at first straight and smooth, then as growth proceeds it coils upon itself, and may acquire a keeled, ribbed or nodular surface. Finally, if the species be a Jurassic or Cretaceous form it is apt to uncoil in later life, and the uncoiled part of the shell tends to become smooth and relatively straight like its own young stage. D'Orbigny observed these facts even before Hyatt, and they are well authenticated by numerous students of the group. Hyatt, however, pointed out the interesting *fact* that there is a parallelism between the growth-stages of the individual, and the genetic succession of species through which the race has developed. For example, the young shell is smooth and straight as were the adult shells of its primitive nautiloid ancestors of Cambrian times. The adult shell is coiled and ornamented as were those of the ammonites of the Devonian when the race was dominant. The old shell is again straight and smooth as were its Cambrian ancestors and the vanishing remnants of the race that died out in upper Cretaceous times. Thus the growth-phases of the individual—embryonic, larval, adolescent, adult and old age—are correlated with the changes which occur in the geological history of the group to which it belongs.

It may be a mere coincidence, but certainly in ammonites there is a surprisingly close correspondence between the growth-stages of the individual and the phylogeny of its race. Hyatt believes that this fact is not due to accident, but that the life of the individual and the life of the race are related and obey one and the same law.

Zoologists can not understand why this must necessarily be so, but there are many laws in nature which man has discovered, and the logical necessity for which we have not yet understood, and its incomprehensibility has naught to do with the truth or falsity of Hyatt's theory.

One can not, however, establish a general law upon the study of a highly specialized race of animals such as the shell-bearing cephalopods, and we must search through the entire animal kingdom to thoroughly test Hyatt's hypothesis; and zoologists have not yet done this, for the paramount interest in studies of heredity now centers around Mendel's law. Yet Hyatt has raised a burning question—is the course of evolution a predetermined thing, and do the growth-stages of the individual reveal to us the past, present and future of its race? Hyatt says they do, for he states that organisms tend to produce offspring varying in a certain well-defined direction so that we may indicate with tolerable certainty what species a given form can or might produce.

It is sad to think that so few young men have followed him into this great field of study, for a student's life is not wasted even if after years of labor he discovers that his preconceived hypotheses were false and he can not fathom nature's secrets, for it is not for science to advocate, but only to search, hoping to discover.

We will now take up the discussion of Hyatt's law of acceleration or *tachygenesis* as he finally called it; although it was commonly known as the "old age theory." According to Hyatt, modifications, once they appear, tend to develop in successive generations at earlier and earlier stages of growth, so that modifications which first appear in adult life or even in old age before the animal becomes sterile will afterwards be developed in the young stages of descendants. Finally, indeed, they appear in the embryos or are crowded out and replaced by later characters. Hyatt believed this law of acceleration to be an invariable mode of action of heredity.

He also believed in the inheritance of acquired characters, and held that the organism is plastic and irritable and responds to external stimuli by internal reactions which manifest themselves as hereditary modifications of structure. It is interesting to see that the recent researches of Tower and MacDougal have shown that artificially produced changes in the environment may affect the germ-cells and produce hereditary modification of structure.

Hyatt maintained that the evolution of new forms has been more rapid than is generally supposed, and in this he has been supported by the classic work of DeVries, who shows how suddenly a new form may appear and maintain itself. It also accords with Bateson's demonstrations of the frequency of "discontinuous variations." As Farlow says: "Our so-called species are merely snap-shots at the procession of nature as it passes along before us."

Hyatt also states that the development of ancestral forms is usually simple and direct; that of their more specialized descendants becomes gradually indirect with complicated larval or intermediate stages; and that of the terminal retrogressive stages, before extinction becomes again more or less direct. Thus the last is like the first.

He states that most existing types arose in early Paleozoic times when evolution was most rapid. Then came a period of slow changes, especially slow in all races which were in the *acme* or most flourishing period of their phylogeny. Finally, when retrogression sets in the pace of evolution again becomes more rapid, and startling *new* modifications are often introduced.

Hyatt acknowledged that natural selection was a factor which modified the course of evolution, but he believed that the history of a race was a predetermined thing and that natural selection played but a minor rôle in comparison with the effects of the environment. In this latter respect he was a neo-Lamarckian; a view which is now more popular than it was at the time of his death.

He believed that when a number of more or less distantly related or even unrelated forms live in the same environment they acquire a resemblance one to the other; the similarity of external conditions producing a "morphological equivalence" or parallelism.

These are the chief features of Hyatt's theories of evolution and heredity. To go deeper into the subject would, I fear, only introduce confusion into the mind of the reader.

The paleontologist possesses at least one advantage over the student of existing animals in that he may observe the changes that develop during thousands of generations, whereas the zoologist sees the present but dares not even vaguely guess upon the future of the race he studies. Accordingly, Hyatt made little impression upon zoologists, but some of the most brilliant paleontologists have applied his principles to the unraveling of the genealogy of fossil and living animals. We need only mention the classic studies of Professor Charles Emerson Beecher upon brachiopods and trilobites, or the many researches of Hyatt's former assistant, Professor Robert Tracy Jackson, at present one of the most progressive leaders of the Hyatt school, among whom are such active investigators as Bather, Buckman, J. M. Clarke, Cumings, Grabau, Ruedemann, Stanton, J. Perrin Smith, Burnet Smith, Schuchert and Van Ingen. In the untimely death of Professor Beecher in 1904, the school suffered a most serious and almost irreparable loss. The general attitude of zoologists toward Hyatt's theory of evolution is probably best expressed by quoting from two of the letters which Charles Darwin wrote to Professor Hyatt in 1872, in which Darwin says:

> After long reflection I can not avoid the conviction that no innate tendency to progressive development exists, as is now held by so many able naturalists, perhaps by yourself. . . . The longer I live the more I become convinced how ignorant we are of the extent to which all sorts of structures are serviceable to each species. But that characters supervening during maturity in one species should appear so regularly as you state to be the case in succeeding species seems to me very surprising and inexplicable.

Hyatt believed in the inheritance of acquired characters. By such he understood modifications which appear in adult or late stages of growth, and are due to the influence of external conditions and not caused by heredity. Probably the most interesting and important paper which Hyatt wrote is his "Phylogeny of an Acquired Characteristic" published in the *Proceedings of the American Philosophical Society* in 1893. In this he shows that at first the young shell in the nautiloids is nearly straight, but soon the shell bends around and grows over the outer side of its older part. The cross section of the young shell before it overgrows itself is round, but when it presses against its first whorl it is squeezed inward on one side, or impressed. This impressed region is due entirely to the pressure of the shell in overgrowing its older whorl, for in the Silurian and Devonian nautiloids the shell does not become impressed until it actually comes in contact with the older whorl, and is thus squeezed inward on its inner side as it passes around the outer side of its older part. That this is due solely to pressure is shown by the fact that when these Silurian and Devonian forms uncoil the impressed zone disappears at once in the uncoiled part, the cross-section of which is round as in the young shell before it grew over its first-formed whorl.

In the Carboniferous species *Coloceras globiatum,* however, the impressed zone appears in the young whorl *long before* it has touched and grown over its first whorl, and in the Jura *most* of the nautiloids develop an impressed zone before the shell touches its first whorl. As Hyatt states, the character has become hereditary and appears at an earlier stage than in the Devonian ancestors. There is also a quicker development of the coiling tendency in Jurassic shells and still more so in the Cretaceous.

It is hard to escape the conclusion that this is actually an acquired character which becomes hereditary, and finally appears at a stage earlier than that in which it first developed. Indeed, it is one of the classic instances of an acquired character, and one of the best established cases of this sort in the whole field of zoology.

In order to establish these interesting facts Hyatt was obliged carefully to crack apart a large collection of nautiloid shells to make a microscopic study of their earliest whorls.

In 1889, Hyatt published his final paper upon the "Genesis of the Arietidæ," a large family of the ammonoids. He agrees with Neumayr that three of the four great branches of this family are descended from a single species, *Psiloceras planorbe,* which was itself derived from *P. caliphyllum* of the northeastern Alps. The race then migrated into Italy, south Germany, and the Cote-d'Or in which last place new progressive forms migrated back again into the northeastern Alps and thence during Bucklandian and later times into parts of Germany, Italy and central Europe. Hyatt carefully traces out the complicated genealogy of the related forms and describes their migrations, and his monograph is beautifully illustrated by heliographic plates. In order to carry out these studies, he visited the museums of Stuttgardt, Tübingen, Würzburg, Munich, Zurich, Paris, Semur, the British and Geological Society Museums of London, and other places in Europe.

In 1872–73, Hyatt lived in Würtemberg in order to study ammonites and also variations and evolution of the fossil snail shells *Planorbis* from the ancient Tertiary lake at Steinheim. As is well known, this lake gradually filled with gravel and limestone mud, and thus the later shells lived at higher and higher levels until the lake became wholly dry. Hyatt agrees with Hilgendorf that all of the species of *Planorbis* found at Steinheim are descended from four varieties of *Planorbis levis* which entered the lake in early times. At first hybrids were developed between these four varieties, but as the original stocks diverged more and more one from another, these hybrids died out. Hyatt finds that in all four stocks there is at first a tendency to increase the spiral of the shell due to a deepening of the lower at the expense of the upper umbilicus, thus eventually producing more or less trochiform shells. Hyatt states that the Steinheim shells develop similar species in many separate and distinct genetic series, and these parallelisms he ascribes to the fact that all lived in one and the same environment and were subjected to similar external influences. His genealogical series differ considerably from those of Hilgendorf, and the Steinheim shells must be restudied by some unbiased investigator before we can be certain of the facts in the controversy. Hyatt found that the young shells are always smooth, but in one race transverse ridges appear on the outer whorl and finally affect the inner whorls of their descendants. Uncoiling also appears first in the outer whorl and finally the inner whorls also uncoil, and in another stock a keel-like ridge forms first on the outer and afterwards extends to the inner whorls. Thus these characters are accelerated, *i. e.*, appear earlier and earlier in the lives of the descendants. Hyatt concludes that the modifications of the Steinheim shells are due to the law of heredity with acceleration, and are not controlled by natural selection, although natural selection may have caused the dying out of the hybrids between the four original varieties. He also believes that gravity produces modifications of structure, and that unfavorable conditions cause uncoiling, produce transverse ridges and diminish the size of the shells. He states also that "the tendency to earlier and earlier inheritance in successive generations is apparently the result of disturbing and modifying agencies acting from without."

For the last twenty years of his life Hyatt studied the mutations and migrations of those most interesting of variable snails the Achatinelidæ of the Hawaiian Islands, and, indeed, he was upon the point of visiting Hawaii when death overcame him in 1902. It is very unfortunate that he never fully wrote out the results of his studies upon these shells, the manuscript which was found after his death being very incomplete, especially upon specific points, and although many of his descriptions of the species themselves were completed, yet his conclusions respecting their relationships and migrations are only vaguely referred to. He did, however, publish a short paper in *Science* in 1898 in which he finds that there are about 280 species of land snails on the island of Oahu, with three leading genera, *Bulimella, Achatinella* and *Apex*. All of these are probably descended from the recently extinct *Achatinella phæozona* of Kiliouou valley, whence they migrated northward, and are now found chiefly on the western sides of the range of mountains which extends along the eastern shore of the island.

Only a very few Achatinellæ crossed the broad lowlands in the middle of the island, and reached the range along the western coast. Species of *Apex*, however, crossed these lowlands and now thrive on the western range, but do not live well on the seaward face of either the eastern or the western range of mountains. The Bulimellæ are confined to the high parts of the eastern range, but have not crossed the lowlands, and are not found upon the western range of mountains. Hyatt saw that the Achatinellidæ of the Hawaiian Islands afforded a preeminently favorable opportunity for the study of the effects of physical conditions on structure. He knew the stock from which he could trace the migrations of the various descendent races, and he became familiar with the different physical surroundings to the effects of which these races were subjected. Thus he felt that he could demonstrate conclusively the effects of environment upon the structure of the shells, and perhaps upon the soft parts of the animals. This research would, had he completed it, have been his masterpiece, and would have added greatly to the world's store of knowledge.

In 1888, Hyatt published in the *Proceedings of the Boston Society of Natural History*, his final paper upon the "Larval Theory of the Origin of Cellular Tissues," in which he maintains that the metazoa are descended from colonial forms of protozoa, and the metazoa may be regarded as complexes of multicellular colonies in which growth by sexual union and resulting fission of the ovum leads to the formation of three primary body layers enclosing an archenteron. *Volvox* or *Eudorina* are forms intermediate between metazoa and protozoa, and may be called *mesozoa*, being multicellular colonies composed of only one layer of closely connected cells forming a primitive tissue.

Hyatt's scientific papers and published discussions cover a wide range of subjects and include such titles as the temperature of caves and wells; the absence of distinct marks of glaciation in Alaska; rock ruins at Niagara Falls; the chasms of the Colorado; a disintegrating rock at Salem, Mass.; Atlantic shore changes; a raised beach at Marblehead Neck; the porphyries of Marblehead; geological survey of Essex County, Mass.; moulting of the lobster; malformation in lobster's claws; and biographical notices of George H. Emerson, Lucretia Crocker, Spencer F. Baird, Jules Marcou and T. T. Bouvé. Unfortunately, his style is confused, for he uses too many adjectives and subjunctive clauses, and rarely presents summaries of his conclusions. The complexity of his elaborate terminology also tends to deter the general reader, and he never sought to present his theories in simple language.

His productive period began immediately after the publication of Darwin's "Origin of Species" and ended just before the rediscovery of Mendel's law of heredity; thus he was one of the leaders in that active discussion of evolution during that speculative period which has now been superseded by direct experimental tests of the theory itself.

His last published papers are upon fossil cephalopods. In 1900, he completed the revision of the nautiloids and ammonoids for Eastman's translation of Zittel's "Handbuch der Paläontologie"; and after his death a manuscript upon "Pseudoceraties of the Cretaceous" was found lying upon his desk practically completed, he having written upon it on the last day of his life. This work was edited by Dr. T. W. Stanton and published as Monograph No. 44 of the U. S. Geological Survey in 1903. The last paper bearing his name was in cooperation with Professor James Perrin Smith upon the "Triassic Cephalopod Genera of America" and was published by the U. S. Geological Survey in 1905, consisting of 394 pages and 85 plates composed of photographic reproductions from the specimens themselves. For many years Hyatt was paleontologist upon the U. S. Geological Survey and these later papers were the results of his labors in this field.

He was elected to membership in the American Academy of Arts and Sciences at Boston in 1869 and was one of its vice-presidents at the time of his death. In 1875 he became a member of the National Academy of Sciences, and in 1895 of the American Philosophical Society of Philadelphia. He was also a foreign member of the Geological Society of London, and was associated with other leading scientific societies both at home and abroad. In 1898 he received the degree of LL.D. from Brown University, and he was one of the founders and the first president of the American Society of Naturalists.

His broad interest in all departments of knowledge, and his generous heart and kindliness to all about him caused him to be surrounded by a host of warm friends whose regard for him increased as years passed by. Thus it was that he was a prominent member of those remarkable social clubs of Boston which strove for the uplifting of humanity, and for the refining and perfecting of ideals of culture. Such were the Chestnut Street Club, a literary association numbering Longfellow, Emerson and Holmes among its members; the Examiner's Club composed of intellectual and clerical men who met to discuss religious and scientific topics; The Thursday Club, a social and intellectual organization; and the Round Table Club, which was for years presided over by Colonel Thomas W. Higginson and met for the discussion of sociological, educational and political subjects. Another organization of intellectual men was known simply as "The Club" and met for discussions of many interesting topics at the houses of the various members, all of whom were Cambridge men, such as William James, Horace and Samuel Scudder, Putnam, Trowbridge, Gilman, Dr. Hildreth, Thorndike and Justin Winsor.

Hyatt was keenly appreciative of the natural beauty of the primeval American landscape which man had done so much to desecrate, and he was deeply interested in the conservation of the forests which still clothed our mountainous regions. Thus he was one of the original members of the Appalachian Club, and served as its president in 1887.

On January 15, 1902, he died suddenly of gout of the heart while he was standing in Harvard Square intending to leave Cambridge to attend a meeting of the Boston Society of Natural History. As Professor William H. Dall says in his biography published in 1902:

> No one who had the privilege of Hyatt's acquaintance but will join in testimony to his high-minded scientific integrity; the infectiousness of his hearty enthusiasm; the fertility of his imagination, which yet was always controlled by constant reference to experience and observation; and the general atmosphere of good-fellowship which he diffused. Unpretentious, open-minded, a constant example of clean living, high thinking and unassuming kindness to all about him, an ideal husband and father, a steadfast friend; we shall not soon look upon his like again.

He lived in a large wooden house built in the New England Colonial style on Francis Avenue in Cambridge. This place he named "Norton's Wood," for it was adjacent to the forest which still remained upon the old estate of Professor Charles Eliot Norton. The open-handed hospitality of his home was a heritage from his youthful years at "Wansbeck" in Baltimore, his house being a center for that delightful intellectual social life of the days when Cambridge still retained its traditions as a college town apart from the overwhelming influence of Boston. None of his three children sought to follow him in the study of science, although it may be of interest to observe that both of his daughters became sculptors, the scientific accuracy of their work being remarkable even apart from its artistic merit.

After his death, biographies were written by C. E. Beecher in the *American Journal of Science,* W. O. Crosby in the *Bulletin of the Geological Society of America,* Samuel Henshaw in *Science,* William H. Dall in The Popular Science Monthly, and the Boston Society of Natural History published an account of the proceedings of its Hyatt Memorial meeting, all of these appearing in 1902. In 1903, Professor A. S. Packard wrote an appreciative biography in the *Proceedings of the American Academy of Arts and Sciences,* and in 1904 T. W. Stanton wrote a sketch in the *Proceedings of the Washington Academy of Sciences,* and finally the late Professor William K. Brooks published a memoir of Hyatt in the "Biographical Memoirs" of the National Academy of Sciences, Volume 6, 1909, this paper containing a chronological list of the titles of his published papers. In 1885 a contemporaneous biography of Hyatt was published by Ralph S. Tarr in volume 28 of THE POPULAR SCIENCE MONTHLY.

IBSEN, EMERSON AND NIETZSCHE; THE INDIVIDUALISTS

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THE development of various phases of individualism is one of the striking phenomena of the nineteenth century. We are not yet far enough away from it to be sure how it will look to our eyes when it has become somewhat definitely measurable as the actual past, but it is not a wild conjecture to think that it will then appear as the individualistic century. In the world of letters Ibsen, Emerson and Nietzsche were three of the more significant, not to say the three most significant, apostles of individualism. They are interesting in comparison, because they represent quite different phases of the individualistic spirit and find their inspiration in somewhat different sources at the same time that they were contemporaneous and were each the product of a general tendency of their time. They illustrate that responsiveness to the common tone of an age that often surprises us in great men who have seemingly been not at all subject to the same specific influences.

There were three major subjects of human thought within which originated the presuppositions that were the foundation for individualism. These were religion, political economy and biology with its related sciences. When at the house of the centurion Cornelius in Cæsarea, Peter said that he perceived that God was not a respecter of persons, but that in every nation he that feared him and respected him was acceptable to him, the Christian religion was set forward on that course that was to bring man finally to a larger hope and trust for himself and all his fellows. For several centuries, for the first twelve hundred years following the founding of the Roman Catholic ecclesiastical system, indeed, the church meant little for either morality or the individual man. It was the church itself, its organization and its further establishment, that was of first moment, but with the Protestant reformation the fundamental Christian sense of human values at once became more active in society. When it became "the dissidence of dissent" in the new world and particularly when it became New England Congregationalism, that sense of value had made the individual human being of first importance in the world. That consequence of the development of protestantism was carried still further by the weakening of Calvinism in the New England churches and by the warmer recognition of the interest taken by the Son of God in every man, Jew or Gentile. It was not solely because New England was in the north that the abolition sentiment was so strong there in the fifties. It was largely because in the eyes of New England congregationalism the black man had a soul, as, in the same sense and degree, he could not have to the eyes of the presbyterianism and the episcopalianism that were dominant in the south.

The growth of individualism as a part of the political activities originating at the close of the eighteenth century is so obvious and so familiar as to come well within the common knowledge of every one, but the contribution of science to this movement of thought in the nineteenth century is not so easily apparent. The first significance of the doctrine of evolution, the great contribution of biology to science in the nineteenth century, was doubtless that of a lessening of the dignity of man. The importance given to man in the expansion of protestant theology, in which he was more and more pushed forward to the honor of co-heir with Christ, was at once denied by implication in the thinking of the followers of Darwin. A creature that had risen out of the brute was very doubtfully filled with that divine essence that made him rightfully a ruler of the universe equally with all other men as being in the same degree with them one of the sons of God. Science here, therefore, gave individualism no promise upon which it could establish itself in the essential nature of man. On the other hand, the Darwinian presentation of evolution as a process did furnish such a premise in the process itself. It was through the struggle for existence that man had come to be man. In this struggle it was some quality or qualities of the individual that raised him above the mass and kept the evolutionary process going forward. That understanding of the nature of the forces that shape life for us transformed the conceptions of the last century and put a new emphasis upon social efficiency in the individual as the first element of progress. In the United States all of these influences, the freedom of extreme protestantism in religion, the general doctrine of political and human equality, and the acceptance of the principle of evolution, have been more free than elsewhere to combine in producing an extreme form of individualism. Of these several influences, however, the spirit of an advanced protestantism seems to have been the most distinctive and the most peculiarly active.

It is as an ultimate product of the most liberal and progressive religious thinking of the new world that Emerson is an individualist. It is also, to be sure, as a philosopher working out in his own way a transcendentalism that goes back to Kant, but the philosophy is so deeply interpenetrated with religious feeling and is so largely turned aside to religious uses that we may call it religion. Everywhere, however, it is the religion of the individual soul, a religion that finds its support in an unfaltering faith in the worth of the individual. In "Self-Reliance" he says:

Let a stoic arise who shall reveal the resources of man and tell men they are not leaning willows, but can and must detach themselves—that a man is the word made flesh—and that the moment he acts from himself, tossing the laws, the books, idolatries and customs out of the window—we . . . thank and revere him.

Further on in the same essay he says again:

The secret of fortune is joy in our own hands. Welcome evermore to gods and men is the self-helping man. For him all doors are flung wide. Him all tongues greet, all honors crown, all eyes follow with desire.

This is all open and unmistakable individualism, and that it is individualism on the religious basis is clear when, in the same connection, he speaks of a greater self-reliance as "a new respect for the divinity in man."

This, indeed, is in an essay that suggests the note of personal aggressiveness, but we shall not find it otherwise in the essays on "Love" and "Friendship." In the one he says:

Thus we are put in training for a love which knows not sex, nor person, nor partiality, but which seeketh virtue and wisdom everywhere. . . . We are often made to feel that our affections are but tents of a night. Though slowly and with pain, the objects of the affections change, as the objects of thought do.

In the other he says as the conclusion of the whole matter:

I do then with my friends as I do with my books: I would have them where I can find them, but I seldom use them. We must have society on our own terms, and admit or exclude it on the slightest cause. I can not afford to speak much with my friend. If he is great he makes me so great that I can not descend to converse.

Here even the offices of what are normally the most unselfish of the personal relations of life are conceived of as having their aim and end in the development of self. Life finds its fulfilment in an approximation to the divine possibilities that are the natural heritage of every human being, and in attaining to that one must not permit himself to be materially hindered by consideration for others. Part of the divine perfection is doubtless expressed for Emerson in the Sermon on the Mount, but it seems clear that he contributes his share toward that questioning of the ethical system of Christianity which now centers upon that portion of the gospel. He does not put himself explicitly in opposition to the beatitudes, but he exalts a spirit and a philosophy in which their teaching is more or less negligible. This, perhaps, is little more than saying that with Emerson protestant theology had passed out of the stage of bondage to the letter, but the forces at work in the change were those of a deeper regard for the powers and capabilities of the inner man, a deeper wish that there should be no check upon their expansion to their fullest possibilities. How large these were in his conception of them may be seen in the essay on "History."

I can find Greece, Palestine, Italy, Spain and the Islands—the genius and creative principle of each and of all eras, in my own mind.

It was in the same spirit that he spoke slightingly of travel. Man could find nothing in foreign countries beyond what he took there, because, if he would be fully himself, if he would bring himself to completion, he would find the whole world in himself. That was the sufficient warrant for feeling that society was not important, but man the individual, man, too, not as in society and a part of it, but man as a separate entity realizing his kinship with the divine in his own way for himself.

There is this same word again in the conclusion of "The American Scholar."

> Is it not the chief disgrace of the world, not to be a unit—not to be reckoned one character—not to yield that peculiar fruit which each man was created to bear, but to be reckoned in the gross, in the hundred, or the thousand, of the party, the section, to which we belong? . . . We will walk on our own feet; we will speak our own minds. . . . A nation of men will for the first time exist, because each believes himself inspired by the Divine Soul which also inspires all men.

The background for the individualism of the German philosopher Nietzsche was in most respects very different from that of Emerson. There was this much in common between them that they both came of clerical stock and that in a way they both reacted from the religious bias that seemed so to have been given to their lives. Beyond that superficial resemblance in the influences playing upon them, they differed radically in the way in which they responded to the teachings of Christianity. Emerson may be said to have been a natural development of the puritan spirit, unique, iconoclastic, reconstructive, to be sure, and yet a puritan clergyman, who, as Woodberry says, never wholly escaped the black coat. In every fiber of his being he was first and last a moralist, one who passed out of the negations of puritanism to its affirmations, and yet essentially a puritan moralist. The one thing that most marks Nietzsche's individualism, that distinguishes it vitally and unalterably from Emerson's, is its intense opposition to Christian morality. This hatred of the whole Christian system has its ground in his conception of Jewish morality as a slave morality. Christian ethics are, to his view, the product of a religious system and teaching, the end and purpose of which is that of giving weakness an advantage over strength, of making the slave the ultimate lord of his master, of raising a subject race to a sense of triumph over its enemies and conquerors. This to his mind is a monstrous perversion of things, for, as he says in "A Genealogy of Morals":

> To demand of strength that it should *not* manifest itself as strength, that it should *not* be a will to overpower, to subdue, to become master of, that it should *not* be a thirst for enemies, resistance, and triumphs, is as absurd as to demand of weakness that it should manifest itself as strength.

This demand is the demand of the Christian system, and, to quote Nietzsche again from the same volume:

It was the Jews, who, with the most frightfully consistent logic, dared to subvert the aristocratic equation of values (good = noble = powerful ≐ beautiful = happy = beloved of God), and who, with the teeth of the profoundest hatred (the hatred of impotency), clung to their own valuation: "the wretched alone are the good; the poor, the impotent, the lowely alone are the good; only the sufferers, the needy, the sick, the ugly, are pious; only they are godly; but ye, ye, the proud and potent, ye are for aye and evermore the wicked, the cruel, the lustful, the insatiable, the godless; ye will also be, to all eternity, the unblessed, the cursed and the damned.

This is what Nietzsche calls the slave revolt in morality, and with the present triumph of the Christian system that here had its source he sees a transformation of the values of the terms good and bad that has been more or less destructive of the fine ideals of the human race. Evil has gained the upper hand. He says again:

The two antithetical values, "good and bad," "good and evil," have fought a terrible battle, a battle lasting thousands of years. . . . The symbol of this struggle, in letters which remained unreadable above the entire history of man until now, is called "Rome against Judea, Judea against Rome." So far no greater event has occurred than *this* struggle, *this* question, *this* deadly inimical antithesis. Rome felt in the Jew something like the embodiment of anti-naturalness, its anti-podal monster, as it were; in Rome the Jew was looked upon as "convicted of hatred against all mankind"; and rightly so, in so far as we have a right to connect the welfare and future of mankind with the unconditional dominance of aristocratic values, Roman values. . . . The Romans, we know, were the strong and the noble, so that stronger and nobler men had never existed on earth before, nay, had not even been dreamt of. . . . The Jews, on the contrary, were that priestly class of people of resentment *par excellence*, which was possessed of an unparalleled, popular ingenuity of morals.

It was as an intellectual aristocrat, a believer in aristocratic values, that Nietzsche set forward in his development as an individualist. He began his life work as a philologist, and Greek was his especial philological interest. His studies in this field brought him under the influence of Greek ideals of power and beauty, dionysiac ideals of abandon, of unrestraint, of free joy, as opposed to the moral conceptions involved in the worship of Apollo. This point of view appears in his first philosophical book, "The Birth of Tragedy." In its first form this title had the additional phrase, "out of the Spirit of Greek Music," and this is significant as revealing his sense of the greatest of the arts as having its origin in the vague and wandering impulses of free feeling rather than in moralizing and reflective thought. Here was the origin of that sense of final values upon which his philosophy is built. The thing of most worth in the world is not the average man and his happiness, but the select man, the man who answers Yea to all of life, the man who takes tribute of other men and lives gladly and freely and fully, obeying his instincts and ignoring the common priest-taught, slave-born distinction between good and evil. Power, intellectual and physical, the power to do a thing, to conquer others, to use men of less power for his own ends, is the mark of an excellence that should suffer no check from the plebeian teachings of a Jewish and slave morality.

To the influence of the Greek spirit as Nietzsche felt it there was added the influence of Schopenhauer to whom he was indebted for his conception of the highest instinct of man as being "The Will to Power." For him this will to power is so fundamental a part of the natures of all men of the higher sort that he finds in it the motive for the imposing of punishment upon those who injure the state or their fellow men. He says:

> By the administration of punishment against the debtor the creditor will become a sharer in a *privilege of the master*. At last he also will for once be inspired by the elevated feeling of being allowed to despise and maltreat somebody as being "lower than himself," or, at any rate, in case the proper power of punishment, the executive power, has already passed to the authorities, the feeling of seeing him despised and maltreated.

This is but one phase of what he calls "the true nature and function of life, which is *will to power*." We hear a great deal lately of the superman, and we are likely to associate the conception with the name of George Bernard Shaw, but he has borrowed it from Nietzsche. If the select few are left free to exercise this "true nature and function of life," as they will, they may develop into an order of beings of higher tastes and greater powers than are exhibited by man in the present. This process, however, can not go on to the evolution of the superman as long as society is under the dominance of a slave morality of which the first consequence is a transformation of values by which the humble and the lowly and the weak are made the equals of the strong and the victorious and the successful.

Of this individualism in Nietzsche it is to be observed first that it is based primarily on a personal predilection. The circumstance that Nietzsche finds some human qualities admirable and others contemptible is not a sufficient ground for the establishment of a system of ethics or philosophy. A preference for the Roman over the Jew is, after all, but a preference, and Nietzsche does not sufficiently show that it is founded in some clear superiority of one over the other as determined by some recognized standard of worth. In the same way he is personal and dogmatic in declaring that the will to power is the true nature and function of life. He cared for power, but it is not a necessary corollary from that fact that the gratification of the will in the pursuit of power is the distinguishing mark of the nobler man. Nietzsche's individualism here must have another support beyond that of his own sense of values. It happened that just at this time science was presenting a theory of the world order of things that offered the required basis for his views.

Nietzsche frequently displays an antipathy for English thought, irritated apparently by its practical and utilitarian leanings. Nevertheless it was to an Englishman, Darwin, that he was indebted for the substantial support that his thinking needed. It is not evolution, however, that is the support of the Nietzschean individualism, but the Darwinian process of evolution. The thing that is inseparably bound up with Darwinism is the doctrine of the struggle for existence. If we accept the struggle for existence as the most important, or even as a vital factor in the process of evolution, then we may accept Nietzsche's will to power. The one is the reflection in philosophy of what the other is in biology. It is the application to human life of a biological sense of values. The man actuated by the will to power is the one that, succeeding in the struggle for existence, will carry the evolutionary process forward. It does not matter that this idea did not originate in this way in Nietzsche's mind. However personal and illogical it may have been in its inception, we shall yet have to give it a hearing, if we can be assured that it is but the expression in new terms of an established scientific truth so generally accepted in one department of knowledge as to be of universal application in all departments. That is a vital question, vital, not for Nietzsche alone, but also for all of us in all our thinking while we are yet a part of that struggle between individualism and collectivism of which the world will not for a long time see the end.

It is to be borne in mind that there is no general question now of the actuality of evolution, but within the last twenty years there has developed among biologists a wide-spread distrust of Darwinism as an explanation of evolution. It would not do to say that selection and the struggle for existence have been disproved as sufficiently revealing the method of evolution, but they have been very largely discredited. Instead of the Darwinian explanation of the method of evolution there have been proposed a great many other explanations, and those accepting these various theories have naturally been active in showing the weaknesses in Darwinism. In other words, the presuppositions upon which individualism founded itself in Nietzsche's philosophy and in the thought of the world have been very seriously undermined. No one will be so bold as to deny that now as we finish the first decade of the twentieth century, along with the weakening of our faith in the survival of the fittest, we are witnesses of a pronounced lessening of the power of individualism over the human mind. Nietzsche, individualist of the most extreme type though he was, is probably read more than ever, but interest in him is rather interest in what men have thought than interest in what they are still thinking. A recent sign of the reversal of our feeling in this matter is observable in the wide-spread adoption of the Galveston or Des Moines plan of city government, a plan which looks toward organized social efficiency more than it does toward the preservation of individual rights. Nietzsche died in nineteen hundred, too early perhaps to realize that the scientific foundations for the work of his life were crumbling beneath his feet.

Emerson's death occurred in 1882. It must have been then even less clear that the theological basis for his philosophy, if it may be so called, was also in no very long time to lose much of its weight. The idealism that in unitarianism lifted man up to the level of Christ soon wrought a kind of self-destruction by bringing Christ down to the level of man. The exaltation of man, of his individual greatness through his kinship with the divine that was Emerson's especial word ceased to be an exaltation when it reduced the divinity of Christ to a merely human greatness. Protestant theology, going forward to its ultimate conclusions, accepting the results of the higher criticism, studying the Bible as a great but as a human literature, compromising with evolution as a causo-mechanical explanation of the origin of things, finally leaves Emerson's individualism without any sufficient body of supporting voices in the house of his friends. There remain, to be sure, the christian scientists. They derive from Emerson, and, with a beautiful blindness to the results of both christian scholarship and the conclusions of modern science, they push the Emersonian ideas to a point at which they become nonsense. Theirs is a beautiful madness, but it is madness. They represent only the aberrant tendencies of more or less unbalanced minds. Their belief that each human being may be the master of himself, his body and the material world, may be himself a kind of God, if he wills, does not go far in support of individualism as a general feeling among men. It was otherwise with Emerson. He and those of his fellowship were enormously influential in American thinking. It may be doubted whether any other man has been equally important in shaping the ideals of the more intelligent classes in America. It is something of moment when on one side that influence is breaking down and on another is turning into the vagaries of people who clutch at cobwebs spun out of the froth of some fanatic's ravings.

One thing is to be borne in mind and that is that the truth or falsity to be found in either Emerson or Nietzsche is for the moment of no matter. It is sufficient as explanation of the growing preponderance of socialistic over individualistic tendencies to show that two of the fundamental inspirations for individualism as seen in them are materially less active forces in society than they were twenty or thirty years ago. If that were mere change of sentiment, it would be of less importance. The fact that it is not sentiment, that it is a change of front resultant from a changed understanding of what the world is for man, and that it is a new establishment of values of things for man to achieve and be makes it significant. A decade or two makes now such an addition to the body of facts that come into the range of human knowledge that the effect may be complete subversion of previously entertained opinions except in the case of men whose sentiments are so strong that they cling to what they have believed the more tenaciously the more it is assailed. Public opinion as a whole shapes itself in agreement with the new facts. It is new facts and fuller interpretation of the old facts, not merely a refluent wave of human feeling, that is responsible for the current trend away from individualism.

Ibsen died in nineteen hundred and six, and so he must be reckoned as of both the nineteenth and the twentieth centuries. He was an old man then, however, over twenty years older than Nietzsche was when he died, and naturally the real body of Ibsen's work was done by the end of the nineteenth century. Nevertheless, he was a man whose thoughts looked forward to our day as Emerson's did not and as Nietzsche's did not. He was an individualist as they were, but he was not an extremist, he was not a man to see the world from one view-point only, he was not narrow or intellectually provincial. That he went with the current ideas of his time as fully as either Emerson or Nietzsche, however, is easily apparent, and it is quite as clear that he was intensely an individualist. What could be more thoroughly individualistic than the words with which Dr. Stockmann ends "An Enemy of the People"? "You see," he tells his wife and children after the utter defeat of all his plans for the good of the community, "You see, the fact is that the strongest man upon earth is he who stands most alone." The two plays that probably more than any others have interested the general reading and play-going public, "Ghosts" and "A Doll's House," are both of them declarations—positive and negative, of the same thing, the right of the individual to develop his own life in his own way according to the needs of his own nature without too close a regard for the demands of society. When at the end of "A Doll's House" Nora is leaving her husband and children and Helmer protests that before all else she is wife and mother, she answers: "I no longer think so. I think that before all else I am a human being just as you are; or at least, I have to try to become one." It is in fact just the individualism in this play and in these words that has made it in a sense the distinctive and notable play of the nineteenth century. It is a human cry for emancipation, for freedom, for self-realization, and it is a cry that Ibsen reiterates again and again through his dramas, demanding that man shall realize himself, but also that he shall realize his best self. It is his peculiar virtue as an individualist that he is held back more or less by the feeling that no man realizes his best self without taking his fellows very largely into account. That is the summing up of his word in "Brand."

Ibsen can not be reduced to a formula. In a measure we may so deal with both Emerson and Nietzsche. We can express the one with some completeness in the term "the oversoul" and the other in the phrase "the will to power," but it was Ibsen's nature to look more carefully at both sides of the shield. That seems to have been the consequence not so much of any greater sureness or clarity of thinking as of a wider range of human sympathies. Emerson wrote beautifully about friendship, but he did not concern himself greatly about his immediate relations with his friends. It was difficult to engage his interest deeply in the affairs of the community or the state or the nation. It seems a fairly reasonable assumption that any man who, theoretically or in fact, is to determine the forms that life as a social whole shall take must be a man who has a deep interest in his fellows, a man of warm social instincts. Only as he is such a man can he come to understanding of those things that man demands in his social order, and no social order can succeed unless it founds itself as carefully upon man's instincts and needs as it does upon the laws that man has discovered in nature. Ibsen felt this as apparently neither Emerson nor Nietzsche did. He was alive to all the political and social movements of his time, and so, because the basal motives of his thinking were rather political than religious or scientific, there was always in his thinking a glance at the whole of society. This kept him full-visioned and sane, and it must be this that Arthur Symons means when he says of him:

> He has less courage than Nietzsche, though no less logic, and is held back from a complete realization of his own doctrine because he has so much worldly wisdom, and is so anxious to make the best of all worlds.

Here we have the significant thing about Ibsen, and it is in this that he is a larger man than either Emerson or Nietzsche, at once an individualist and also a thinker conscious of that check upon the rampant individualism of a Nietzsche that we now feel necessary for the making of the "best of all worlds." Bernick in "The Pillars of Society," seeing that he has not realized himself because he has not sufficiently felt his obligations to society, says:

> Do you know what we are, we, who are reckoned the pillars of society? We are the tolls of society, neither more nor less.

Such a generalization understood as Ibsen meant it, has in it a profounder truth than anything in either Emerson or Nietzsche and it is a truth more immediately in accord with the spirit of the new century whose first years saw him a weakening and a dying man. In the loss of that divine made human in us of which Emerson dreamed we are only men once more, and it is as men that we must make the best of our world, if we do not make it the "best of all worlds." As evolutionists we must at last realize, it seems clear, that the struggle for existence is not and never again can be a blind struggle. Darwin made man a conscious factor in the struggle as soon as he told him that there was such a struggle. As such a conscious factor he is certain to realize more and more that he is able to push the evolutionary process on only as a part of the social whole. It is the gregarious instinct in man that makes him the lord of the brute and civilized man the lord of the savage. So, while the biologist lessens the struggle for existence as a recognized factor in evolution, man nullifies it in organized society for those within the organization, and leaves it to work what havoc it will outside. This is on the way from individualism to socialism, and that is the way we are now going because of our new premises in religion and science and politics. Man, the single man, is to be steadily more and more, no doubt, but it is man in the collective whole that in this century is to croon over him as, in Ibsen's "Peer Gynt," Solveig at last croons over that poor wreck of self-realization gone mad, Peer Gynt himself:

I will cradle thee, I will watch thee;
Sleep and dream thou, dear my boy.

PHYSIOGNOMY AND GENIUS

By CHARLES KASSEL

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SAYS Edwin Miller Wheelock in that great prose epic of evolution which he called *Proteus:*

> Our humanity has been evolved out of the lower and coarser types of life and faces still hang out the signs of this experience in the vulture beak, the bull-dog visage, the swinish aspect. This face is a bear's muzzle; that a snout. This one is written over with a foulness that needs no label; here is a rat and there an abject thing cringing for leave to be. The old brutehood lurks in each cerebellum and the nobler faculties of man sleep in their shell.

Since the uprise of the theory of evolution with its emphasis upon the physical tokens of kinship between man and the animals, the old science of physiognomy, which formed a favorite study of the ancients, and to which the great Aristotle himself devoted six weighty chapters, has come forth from its hiding amidst the discarded superstitions of the past. The time-worn rules for determining character from countenance have gained a genuine interest for the scientific mind, and even the old saws and proverbs—crystallizations of mankind's observation of faces and features for unnumbered generations—have taken on a dignity and value which they could not else have borne.

It is to the criminologists, however, that we are indebted for the first distinct step toward a scientific study of physiognomy, and their labors give hint of the large results which might be possible to an investigation of wider scope. Thus, we are informed by Havelock Ellis, in his interesting and instructive work "The Criminal," that the receding forehead, prognathous jaw, and long, projecting and voluminous ears are in general characteristics of the criminal, while, according to Lombroso, the homicide may be known by his cold, fixed and glassy eye, beaked nose, prominent jaws and cheek bones, thin lips, and, not infrequently spasmodic contractions on one side of the face. "Among petty criminals, those who are criminals by weakness," says Ellis, "a type of receding chin is found," and he adds, "the typical thief's nose is rectilinear, often incurved, short and twisted, with lifted base."

Deep-rooted as is the instinct for inferring character from countenance, it is not a little remarkable that the one ripe and ready field for the study of physiognomy has remained thus long unexplored. The pages of biography should afford rich spoil for the curious delver after hidden laws of mind and morals, and it seems that a tabulation of the faces and figures of eminent personages should long since have suggested itself as desirable, if not indispensable.

Truth to say, however, no ingathering of such data appears to have been made, or, if made, to have been given publication; and, failing statistics at second hand, we have endeavored by search at first hand through some two hundred biographies, to supply the want—less, be it added, as a basis for generalization upon our own part than as an offering of material for study and analysis by others.

The feature of the countenance which first strikes the observer is the eye—the "lamp of the body" as it is called in the new testament, but more fitly, perhaps, the "lamp of the soul," for in very truth the eyes are the lighted portals to man's inner nature. The most noteworthy circumstance which our data offer is the very large predominance of blue, gray and bluish-gray eyes among personages of distinction. Thus, of seventy-six eminent men whose biographies afforded the information, twenty-five appear to have had blue eyes, seventeen gray and thirteen bluish-gray, making a total of fifty-five. Boasting eyes of blue—the color-symbol of goodness, according to the mystics—were Samuel Adams (dark blue), Matthew Arnold, Charles XII. of Sweden (dark blue), Longfellow, Stephen A. Douglas (dark blue), Eugene Field, Stonewall Jackson ("as a child, blue-eyed"), Charles George Gordon (pale blue), Patrick Henry, Oliver Wendell Holmes, Andrew Jackson, Charles Godfrey Leland, Washington Irving (given as gray by some biographers), Washington Alston, James Monroe (blue, approaching gray), Napoleon ("steel blue"), John Ruskin, Savonarola (dark blue), Wm. H. Seward, Shelley, Chas. Sumner ("deep blue"), General Thomas, Grieg, Weber. Among gray eyes—"deep and sly" if we are to heed an old proverb—we have Michael Angelo ("light eyes"), Browning, Cæsar (variously given as dark gray and black), Carnegie, Coleridge (described by other authorities as light hazel), Columbus (light gray), Sir Thomas More, Wm. Hazlitt, Ibsen (pale eyes), Washington Irving (dark gray but, according to others, blue), Thomas Jefferson ("gray flecked with hazel"), Milton (dark gray), Francis Parkman, S. S. Prentiss (dark gray), Robespierre ("pale greenish gray"), Tolstoy, Tennyson (this according to Caroline Fox, but, according to Carlyle, hazel). As representing a blend or play of both colors we have the names of George William Curtis, Charles Darwin, Frederick the Great, U. S. Grant (according to some biographers "dark gray"), Walter Savage Landor, Sidney Lanier, Napoleon (given by others as steel blue), Longfellow (given by other authorities as blue), Theodore Parker, Rossetti (between hazel and blue gray), Thoreau, George Washington, Whitman. It will have been noted that the same name appears occasionally in two of these lists This is owing to a conflict between biographers and the same circumstance will explain a like duplication in future lists.

The brown-eyed men among the celebrities of history were Captain Cook, Goethe (dark brown), Keats (hazel brown), Charles Lamb, R. L.

Stevenson, Bayard Taylor (dark brown), William the Silent and Chopin. The eyes of Rufus Choate, Alexander Hamilton, Fielding, Sir Arthur Sullivan, Beethoven and John G. Whittier are described as "dark," Whittier's being described by most biographers as black. Hazel-eyed were S. T. Coleridge (given variously as hazel and gray), Farragut, Albert Gallatin, Hobbes, Keats (hazel brown), Walter Pater (light hazel, almost gray green), Southey (dark eyes, in youth light hazel), Tennyson (gray, according to Caroline Fox). Black eyes gleamed, according to biographers, from the brows of Cæsar (by others, however, spoken of as dark gray), Leigh Hunt, Paul Jones, John Marshall, Peter the Great, George Ripley, Daniel Webster and John Greenleaf Whittier.

With Agassiz, Peter the Great, R. L. Stevenson and George Washington, the eyes were set well apart, but precisely the reverse was true in the case of Robespierre. The eyes of Browning, Charlemagne, Coleridge, G. W. Curtis, Eugene Field, N. Hawthorne, Paul Jones, Napoleon, Peter the Great, Shelley and Tennyson were large—betokening, according to the "Encyclopedia of Superstitions," a faculty for talking and "for the use of effective language"; whereas those of Captain Cook, Patrick Henry, Ibsen, John Marshall, Tolstoy, Whitman, Chopin, Beethoven and Michael Angelo were small. As possessed of deep-set eyes—surrounded in the majority of instances by high arching eyebrows—we have the names of George W. Curtis, Darwin, Stephen A. Douglas, Eugene Field, Fielding, Gladstone, Alexander Hamilton, Patrick Henry, Huxley, Thomas Jefferson, Andrew Jackson, Paul Jones, Landor, Thoreau, Tolstoy, George Washington, Daniel Webster and Whitman. A profound power of observation appears to link with these names—an impression made more marked by shaggy eyebrows in the cases of Curtis, Darwin, Douglas, Jackson, Tolstoy and Whitman.

Next after the eyes, perhaps, the feature of the countenance which impresses the beholder is the formation of the jaw. Even before the lines of the mouth this aspect of the face engages attention. By no mere coincidence, doubtless, does a powerful jaw—the emblem of indomitable will—form the distinguishing marks of such physiognomies as those of Carnegie, Stonewall Jackson, Frederick the Great, Chinese Gordon, Grant, Alexander Hamilton, W. S. Landor, Walter Pater, George Washington, Arthur Sullivan and Schumann, nor does it seem without significance that in the case of Robespierre "an insufficient development of the jaw" is noticeable, and that in the case of Michael Angelo the "lower part of the face was much smaller than the upper." Quite suggestive, moreover, of something primitive, akin perhaps to ferocity, are the high cheek bones of the great navigators Columbus, Captain Cook and Farragut, on the one hand, and Robespierre and Daniel Webster on the other.

The lines of the mouth we never neglect. We naturally scrutinize the lips for impressions of power or weakness, coldness or affection, sensuality or delicacy. Our data here are less full than could be wished. We have no means of trying by the testimony of biography the dislike we feel for lips that are excessively full or which, when smiling, turn upward at the corners, nor can we verify the impression of extreme narrowness and obstinacy which we gain from feminine lips that are thin and bloodless and drawn downward at the end. We seem, however, to discern a marked austerity in the meager lips of Rufus Choate, Farragut, Stonewall Jackson, Frederick the Great, Ibsen, Robespierre, Thaddeus Stevens ("thin upper lip"), U. S. Grant and Paul Jones, whereas in the ampler labia of Coleridge, Cromwell ("strict yet copious"—Carlyle), Nathaniel Hawthorne (full under lip), Oliver Wendell Holmes (protruding under lip), Julian (full lower lip), Peter the Great, Savonarola (full under lip), Beethoven (protruding under lip) and Schubert we might suspect a proneness to self-indulgence. The long upper lip of Landor gives a suggestion of assertiveness and tenacity which seems unmistakable.

Quite disappointing are our data with reference to the chin. That feature would seem entitled to greater weight in any estimate of character than biography appears to warrant. Thus, the chin of long, square, shovel-like structure always drives in upon us a vague shrinking, as from something fanatical, and so a thin and pointed or receding chin carries a suggestion of weakness which moves our pity or contempt; yet such inferences seem unjustified when applied to the distinguished individuals of history, though even our scant data are not without a testimony to general characteristics of disposition as associated with set types of chin.

The chin of Oliver Wendell Holmes, as we find, was decidedly retreating, that of Hawthorne is pronounced "weak"; Defoe and Robespierre had sharp chins, while that of Fielding is described as "unusually long," that of Napoleon "projecting" and that of Parkman as "of unusual prominence." As round or full—a contour pleasing to the eye—we have those of Captain Cook, Charles XII. of Sweden, Eugene Field, Washington Irving, Sidney Smith and Thoreau, which last is described as "strong."

The nose we seem instinctively to look upon as a decisive index to character. We never think highly of the character or capacity of persons with small pinched noses. Pug noses, moreover, we associate with pertness, and long, pointed noses with inquisitiveness. So, the hawk-nose, to most observers, is a sign of an aggressive, self-sufficient nature, not troubled overmuch with moral scruple. We never look for a placid temper among persons whose noses roughen easily into wrinkles, and in those whose noses wrap into long folds down the sides we expect evidences of a sordid make-up. Fine Greek noses, however, we take to be sure indications of good taste—large, shapely Roman noses as signs of solid character, inclining to generosity and capable of wise leadership.

These characterizations, however, seem but dimly borne out by the pages of biography. Thus, as possessed of small noses, we find Stephen A. Douglas, Oliver Wendell Holmes, Thomas Jefferson, James Russell Lowell, Peter the Great, Robespierre, Bayard Taylor and Thackeray (that of Schubert is spoken of as "upturned" and was doubtless small), while the large nose finds representation in the case of Charles XII. of Sweden, Eugene Field, Albert Gallatin, Washington Irving, Rossetti ("large distended nostrils"), Thoreau ("huge"), Tolstoy ("broad"), George Washington ("long in proportion to his face"), William the Silent ("long with wide nostrils"), Beethoven ("rather broad"). The hawk-nose was a characteristic of the warriors Charlemagne, Cromwell, Farragut and Frederick the Great, as also of Columbus ("aquiline"), Defoe, Fielding, Nathaniel Hawthorne, Lamb, Lanier, Savonarola, Sidney Smith, Thaddeus Stevens, Bayard Taylor and Chopin. The straight nose is found in the cases of Captain Cook, Albert Gallatin ("long and prominent"), Alexander Hamilton ("long and rather sharp"), Washington Irving, Paul Jones, Julian, Napoleon and Whitman.

Far more interesting and significant is our material with reference to the foreheads of great men—that popular test of intellect and capacity. Remarkable for high foreheads were Bunyan, Charlemagne, Charles XII. of Sweden, Darwin, Hazlitt, Patrick Henry, Hobbes, Leigh Hunt, Ibsen, Washington Irving, Andrew Jackson (high but narrow), Peter the Great, Robespierre, Walter Scott, Daniel Webster, Beethoven and Schubert. As "broad" we find the foreheads of Carnegie, Agassiz, Charles XII. of Sweden, Captain Cook, Stephen A. Douglas ("massive"), Nathaniel Hawthorne ("massive"), Washington Irving, Paul Jones, Keats (but not high), Lamb, Monroe, Robespierre, Rossetti, Savonarola, Walter Scott, Stevenson, Beethoven. The forehead of U. S. Grant is described as "square"—usually accepted as a proof of fearlessness—while those of Coleridge, Whitman and Michael Angelo are described as "overhanging." The foreheads of Frederick the Great and Robespierre were receding, while those of Keats and John Marshall were low.

It is not without interest that among the physiognomies of the distinguished individuals whose biographies we have examined, we note as conspicuously absent the "prognathous jaw" and "long, projecting and voluminous ears," which according to Ellis are characteristics of the criminal class, and which, it may be observed, are likewise tokens of recurrence to the primitive human type; nor in our studies of the nose have we met the peculiarities of that organ which make up what Ellis calls the "typical thief's nose." An occasional mark of the lesser criminal, such as the receding forehead and retreating chin, make their appearance in our data, and those signs of power in the homicide —the prominent jaw and cheek bones, hawk nose and thin lips—are not without place in the faces of great historic characters, but with a single exception we find no example of the "cold, fixed and glassy eye" which according to Lombroso betokens the murderer. That exception, it is needless to say, is Robespierre, and it is no mean commentary upon the value of such studies as we have been pursuing that the face of Robespierre presented as strange a compound as his soul—that with the signs of strength afforded by the capacious forehead and firmly compressed lips there mingled so many features which the specialists in criminology accept as indications of criminality. His head, we learn, was small, brow retreating, nose diminutive and quite without an arch, jaw insufficiently developed, cheek bones high, eyes set close and in hue a "pale, greenish gray," shadowed by eyelids which trembled spasmodically.

GEOGRAPHIC INFLUENCES IN THE EVOLUTION OF NATIONS

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The Study of Nations.—The study of the chief nations of the world, with respect to their history, government, institutions or people, forms the basis of most of the humanitarian, as opposed to the natural, sciences. Yet in many respects the general attitude adopted in the interpretation of national development has not changed with the advances made in the scientific understanding of the earth in its relation to life. Fifty years ago, for example, the belief was prevalent that the earth was made for man's convenience. Since then the students of the natural sciences have adopted the conception that life is the product of evolution, in which physical conditions are at all times important factors. The study of nations, on the contrary, is still largely carried on from the old point of view, with little or no open recognition of the significance of evolutionary factors.

National Evolution.—For the nation, also, as well as for the individuals of which it is composed, physical conditions are at all times important influences. This principle of evolution, therefore, may be applied to the different stages through which human groups pass in their rise from primitive tribes to modern nations, in the same way as it is applied to the human individual in the evolution of man to his present high estate in the animal kingdom. Thus as the course of human progress replaces the isolated, self-dependent savage by the tribe, or any primitive group, the qualities and motives of the group reflect the needs which arise from the surroundings and also the opportunities at hand for satisfying these needs. The organized hunting tribes of forest dwellers, the pastoral nomads of open grassy plains, the fishing folk of barren coast lands, represent great advances beyond the first savage individuals, yet each of these groups is none the less the combined result of human needs and natural opportunities to gratify needs. Physical conditions are for these groups the most important factors in determining both the character of, and the opportunities for satisfying, human needs.

Each of the above groups represents a stage of progress toward national existence, but no one of them, as they stand, possesses the physical conditions necessary to lift the tribe to the higher plane where it might be said to have true national qualities. Before any primitive group can develop into a nation, it must be given an evironment wherein it may be established and maintained on a permanent basis, with the returns from human efforts exceeding the demands of immediate needs. Under favorable conditions the cultivation of the soil offers such a chance for permanent establishment. Hence agriculture becomes the broad basis on which the development of important nationality may be said to depend, and an environment which permits agriculture is to be considered as a fundamental requirement for a budding nation.

Each nation, in every stage of its development, finds itself confronted by needs which must be satisfied, and it is forced to seek ways of gratifying those needs in order to preserve the national existence. Each nation, occupying its political unit, has in that unit certain natural opportunities which are the result of physical conditions, and which represent the sum total of means available to meet national needs, either directly or indirectly. Hence, each nation in its different stages of past development, in its present organization, and in its future importance, must be considered largely as the product of the physical or geographical conditions by which it has been surrounded.

It does not appear, however, that the operation of these geographic factors is accorded the proper recognition in the study of nations, whatever the guise under which that study is made. Thus, in one of the latest texts at hand, a book designed to complete the course in geography in the schools, a book well thought of generally, widely used, and a fair sample, a half a dozen pages are devoted to the United Kingdom, and less to Germany. A marvelous example, it is, of concentration of facts, but it gives no reasons; no indication of inter-relationship between the nation and its surroundings; no idea or appreciation of the factors which have so closely shaped the whole course of British development; no hint of a real understanding of the nation; it gives simply a collection of statements concerning places and things.

A nation is more than a disorganized array of cities, products and industries. A nation is a living entity: a unit produced by the action of uncompromising physical forces, and its cities, products and industries, at any given time, are but the temporary manifestation of those forces.

The Modifying Factors.—No two nations have been identical in all aspects of their evolution, for no two nations have had identical geographical surroundings. In numerous cases, nations, unlike in important respects, have been composed of people of common origin, as in the case of England and Australia. On the other hand, similarities in physical surroundings have, in every case, produced similarities in development in nations composed of people of different origin, as indicated by Argentine and Australia, or by England and modern Japan. National evolution, therefore, is not a simple question of race, but a more complex question of surroundings and opportunities.

The real understanding of a nation and its evolution depends on an appreciation of the particular combination of physical conditions by which its course has been influenced in the different stages of development. Consequently each nation must be interpreted in terms of its own physical forces, and its strength or weakness may be measured by those forces. The chief physical factors which are important in shaping national development may be grouped, roughly in descending order of importance,[1] under the following general heads: (1) Position with respect to physical relations, (2) position climatically, (3) surface area, (4) surface configuration, (5) productivity of the soil and climate, (6) the possession of potential mechanical energy, (7) mineral wealth.

Physical Position: Separation.—If the conditions necessary for agriculture are assumed to exist, position with respect to physical relations may, on general grounds, be accorded first importance in its effect on national evolution. In the early stages of development of all the older nations, the degree of isolation or separation appears to have been the one significant feature common to all the national territories. This striking similarity may be explained on the ground that unless the primitive group was afforded some degree of protection by natural barriers to attack, the problem of successful establishment and maintenance materially hampered continuity of progress.

A survey of the physical relations surrounding the seats of the early nations of the world indicates the value of separation, since, without exception, they all possessed that quality to a marked degree. Thus, Egypt in the Nile valley, highly favored as it was in soil and climate as a basis for agriculture, may be regarded as owing its early development of national qualities and culture no less to the surrounding desert barrier which guaranteed a large measure of immunity from molestation. For, at the same time, other regions, like the lower Mississippi valley, no less fertile, but lacking protective barriers of any sort, have shown no national development by native groups.

Similar conditions of separation and security were afforded in one way or another in the fertile valleys of western Asia, and in the Greek and Italian peninsulas. Considering Europe as a whole, for example, there are nine fairly distinct physical subdivisions, of which four, the Greek, Italian and Spanish peninsulas and the British Isles, have more or less complete separation, by natural boundaries, from the adjoining continental areas. Each one of the four stands as the seat of solid national development at a date earlier than any stable national existence prevailed in the other parts of the continent, as in the exposed sections occupied by the modern states of Germany and

[1] For any individual nation at some particular stage in its evolution any one of these factors may stand first in importance, as noted later.

Russia. The converse of this argument, therefore, suggests the absence of effective separation for any group as an important factor in the failure of primitive tribes to develop nationally on the open plains of eastern Europe or of South and North America. Sections of the last named, at least, were fully as well favored as was the Nile valley, so far as the prosecution of agriculture is concerned.

The measure of separation not only has been a significant factor in the inception of national development, but also appears as one of the chief modifying influences in all the successive stages of evolution. Its effects have been operative both in the case of older nations developing directly from primitive groups, and in the modification of transplanted national civilizations, of which class the Australian colonies and New Zealand may be regarded as typical. Separation has meant more than the security needed in the period of development from the primitive group into a people solidly welded by national qualities and attributes. Through this same lessened liability of molestation, the more perfect the separation, the greater has been the continuity of social and economic evolution, and the more rapid the advance, beyond the preliminary stages of national existence.

Separation, or the lack of it, also determines the absence or presence of the burden of militarism, and hence fixes the extent to which the energies of the population may be profitably occupied or how much of them must be wasted in unproductive military service. Thus the old Prussian maxim that "Empires are made only by the sword" clearly reflects the exposed position of that state, its dependence on armed strength for its existence, and one of the chief factors in its slow development to important nationality.

The sharply contrasted course of events in England, as compared with either France or Germany, must be explained largely on the degree of separation which has always been one of the chief British assets. The early breaking down of feudalism and serfdom in England and the consequent more rapid advance of personal and political liberty, the freedom from invasion and wars on her own soil, the absence of any powerful rival occupying contiguous territory and the resulting freedom from a great military burden, all represent tremendous advantages, possessed by none of her rivals. All these advantages depended on the separation of England from the continental mainland, by a narrow body of water, the crossing of which was rendered difficult and hazardous by its turbulent waves and currents. France, on the contrary, though in many respects naturally better favored than England, was, by her more exposed position, led into the pursuance of continental policies which frequently involved her in wars on her own soil and greatly hampered internal progress. France thereby was held back at times when England, enjoying internal peace, was forging rapidly ahead. Germany, more exposed than either of the others, and less distinctly a separate natural unit, was correspondingly slower in her national development, and may still be regarded as existing largely on a military basis.

Separation and Accessibility.—Separation which amounts to isolation, however, is a handicap, rather than a benefit, to the best national progress, for the reason that intercourse with other localities offers opportunity for distinct stimulus through contact with new ideas. To be of maximum value to a nation, therefore, the physical position must afford ready accessibility for peaceful intercourse. For this reason, the character and quality of the national boundaries are in many ways factors of prime importance in the whole course of economic progress and national welfare.

Britain again affords an excellent example. So placed that her doors were effectually closed to serious interference with her internal development, Britain could, however, from her station opposite the convergence of the great European highways of communication, profit readily from intimate contact with continental ideas. History shows that the people of Britain were not the pioneers in commerce, in exploration and discovery, in colonization, or in the development of manufactures: all important lines of activity wherein Britain excelled in later years, and whence came much of the importance of the British nation in the affairs of the world. In each case Britain got the stimulus through her accessibility for peaceful association with continental neighbors, and in each case the superiority of the British position for continuity of internal evolution, readily enabled her to outstrip all others. This same quality of standing somewhat aloof offers a perfectly natural reason for the long-continued preeminence of British influence in the direction of international affairs among the European nations.

China, by contrast, is not to be regarded as a backward nation, because of some inherent lack of ability in her people, but rather as a nation long suffering from too great separation, and consequent lack of new ideas, in much the same way as a single individual, isolated, suffers from lack of stimulus. Japan, much smaller, both in area and in population, and much more readily accessible, shows in her recent rapid developments the effects of intercourse with, and stimulus from, the outside world. China may be expected to show similar results in the future as her greater barriers of isolation are overcome.

Accessibility by Sea.—Ready accessibility from the sea is more important than accessibility by land. It depends on a favorable combination of coast line, surface configuration back of the coast, and climate. Access from the sea means an open route between many nations: a route which is on the whole more easily travelled than the land for the peaceful intercourse of commercial relations, and more difficult for the movement of a hostile expedition. In this last fact are found the peculiar advantages enjoyed by a country possessing coast boundaries on all sides, like Britain. Without this common, easily travelled, highway, the leading European nations of to-day could not live on their present basis. Access by land alone, along the line of, or even at the convergence of, great natural land routes, such as were so important in the early days of Dutch activity, could not meet the modern demands in the exchange of bulky raw materials for the products of mechanical energy. A list of the countries with no access from the sea is a list of the less important countries of the world, as Bolivia, Switzerland, Servia, Abyssinia, Afghanistan and Thibet. Other countries with seacoasts, but coasts of unsatisfactory character, either because of the absence of good harbors, too great ruggedness of surface, or being ice bound, suffer almost to the same degree, as Peru, and Russia both in Europe and in Asia.

The significance of access from the sea is in one way clearly demonstrated by Russia. During more than two centuries the importance of securing a coast affording ready sea communication at all seasons has been the dominating influence in Russian aggression and territorial expansion. Siberia, with its vast resources, loses most of its value to Russian national development as long as satisfactory outlets to the sea are lacking. The Russo-Japanese war may be regarded as an incident in the long-continued effort to remedy this natural defect. It is not too much to say that the failure of Russia to secure a satisfactory coast and easy access to the common highway of the world accounts for much of the slowness of Russian national evolution, a slowness ordinarily, but wrongly, attributed to the fact that the Russians are of the Slavic, rather than of some other, branch of the Caucasic race.

On the other hand, mere possession of this advantage of a sea coast, avails little unless other conditions are such that it may be used to best profit, as illustrated by the results of the failure of France to utilize, at the dawn of modern commerce, her superior access to the coasts of both Mediterranean Sea and Atlantic Ocean. The reason for this failure must be sought in the weakness of the French position in other directions. For had France enjoyed the internal security and aloofness of England, this direct access to both great commercial highways, backed as it was by the greater size and larger population of the country, the better soil and climate, the natural facilities for internal communication by navigable rivers, and the situation of France with reference to the markets of Europe, would have made France, instead of England, the master of commerce and the leader of all Europe.

The significance of position, therefore, does not cease with the inception of national development, but makes its influence manifest throughout the national existence. In advantages derived from physical position, Britain stands close to the ideal, while Germany or Russia may be taken as representative of the opposite extreme.

Position Climatically. Extremes of Climate.—The seats of the early nations of the world, alike in the matter of separation, do not show the same degree of uniformity in climatic characteristics. Their positions climatically, however, do suggest that the extremes of climate are unfavorable to national development. The extremes of cold and of great aridity prohibit cultivation of the soil and thus immediately remove the essential basis of national development. Far northern peoples and desert tribes may utilize their meager opportunities with much greater skill than the most highly civilized man could, hence with respect to their opportunities they are in no sense backward or unprogressive. Yet the burden of satisfying human needs is so great that the people must remain relatively unprogressive and can not develop nationally. They represent a close parallel to the natives of some of the islands of the Pacific Ocean, where the absence of all metals in the coral reefs has prevented a people, highly skilled in many ways, from advancing into a metal age.

The extremes of heat and moisture, when combined, are conducive to the development of extravagant forms of both plant and animal life in superlative abundance. To conquer these rival forms of life and establish himself successfully on an agricultural basis is a difficult task even for the highly civilized man, with every modern appliance at his command. Primitive man, therefore, under these conditions finds himself generally unable to rise above the plane of the forest dweller. At the same time the small need for clothing and shelter, coupled with the ease of gratifying all physical wants from the bounty of nature, favors inaction which is always hostile to progress. For these reasons, national qualities and civilizations have not been developed among the primitive groups of the equatorial rainy sections.

Intermediate Types of Climate.—The intermediate climatic types are the only ones under which national evolution from the primitive group has taken place and where high stages of national civilizations have been developed. In these cases, the climatic conditions impose demands for food, clothing and shelter, beyond the possibilities of the unaided bounty of nature to supply, yet capable of satisfaction through a fair amount of human effort.

This idea of a climatic stimulus as a basis for human progress and the evolution of nations, is commonly expressed in the phrase "spur of the seasons." Too often, however, the spur of the seasons is assumed to mean a winter, or a period when low temperatures cause plant activities to cease temporarily, and therefore require, for the human being, not only the provision of warm clothing and substantial shelter, but also the accumulation of stores of food. This concept is clearly at variance with the fact that the earliest national developments, of Egypt and western Asia, were in the warmer latitudes, where frosty seasons are absent or not very marked, but where periods of dryness produce conditions in the plant world analogous to the effects of a winter. With the less rigorous, but no less effective, spur of a dry, rather than a cold, season, the fertile protected valleys of the Nile and of the Euphrates naturally developed nations earlier than those localities where the hard conditions of cold winters meant a longer struggle to rise above mere physical needs. The constant operation of this factor of *degree* of rigor in the off season is seen in the successive development of true nationality in the less favored localities, with the least favored advancing slowest of all. Thus the comparatively mild Mediterranean sections of Europe were logical successors of Egypt and western Asia, just as the milder maritime sections of western Europe were the logical predecessors of the more rigorous continental portions, so far as the time of national development was concerned. This climatic factor, therefore, adds another important reason for the slower national evolution in the open plains of north central and eastern Europe, as compared with Britain or France.

Variability of Climate.—Variability of climate may be either periodic, at regular or irregular intervals, or it may be in the nature of apparently permanent change in one direction. Such variation as the latter, whether the change be toward wet, dry, hot or cold, must greatly alter the course of any national evolution already started, as indicated by the evidences of permanent desiccation and consequent depopulation of important sections of the old world. Too much periodic variability of climate, that is, from year to year, or in the form of too long an off season, especially when it is marked by prolonged cold, are almost as great handicaps as the extremes of cold or heat and moisture combined. The unreliability of the Australian climate in practically all the habitable portions, has been, and apparently must be, one of the most important controlling factors in the entire economic development of that country. It is in effect a large scale example of the conditions which brought the Kansas boom, in this country, to a disastrous end two decades ago. The variability of the Indian climate from year to year imposes burdens on the people which hinder greatly the chances for reaching the higher stages in the evolution of India as a nation.

In the same way, too long an off season, particularly a long and cold winter, is a serious obstacle to the best development. Much of the agricultural population of Russia, for example, is forced into idleness through half the year by the length of the Russian winter. Inactivity in itself is hostile enough to progress, but when combined at the same time with the burden of providing against the extreme severities of the long winter, it brings much of Russia close to the border line of those places where the struggle to meet physical needs consumes every energy. For that reason, the character of the winter may be regarded as another factor constantly tending to retard Russian national evolution.

In many instances the value of the climatic variation from season to season, and especially the effect of the cold season, as a stimulus to regularity of effort is over-estimated. In this country, it is true, the cold winters are, to a certain extent an asset, in that during this period of the year great volumes of clear, dry, pure and invigorating air spread eastward from the northwestern highlands. From these "cold waves" comes stimulation, vigor and energy for many of the American people, yet the duration and intensity of the cold, especially in the more northerly sections, impose heavy burdens on a large part of the population. There is such a thing as too harsh a spur of the seasons. Many a Russian peasant is a chronically jaded creature largely on that account; while in this country, the poor are made poorer because of the increased need for woolen clothing, warmer houses and heavier diet. Though commonly passed over lightly, this question of climatic position is at all times of critical importance in the strength and welfare of nations.

Considered from the broad standpoint, the combined influence of physical position and situation climatically determines whether important national evolution may or may not have its inception and advance successfully under the modifying influences of the other physical factors.

Surface.—The configuration of the surface, to which alone so much significance is usually attached, is a consideration of decidedly secondary importance in the evolution of nations, for the reason that similar surfaces, in different positions, show radically unlike results. Thus a national evolution, may in an inhospitable position remain incapable of type of surface which, when well situated, appears most favorable to any real development. On the other hand, a less desirable type of surface in a more advantageous position may serve as the basis for a fairly important nation. The untouched, level Arctic tundras, and the progress of rugged Norway, may be cited as contrasting examples of the importance of position, both physically and climatically, in considering what the surface qualities are likely to induce.

Surface Area.—In the consideration of the surface and its features, the extent of the surface or the area of the national territory, is of primary significance. The influence of mere size varies in the different stages of evolution. During the first steps of national growth a small or restricted area, other things being favorable, quickly produces a condition of compactness, which is at once a source of strength and a material aid in the advancement of national qualities. The familiar description of Britain as "a tight little island" suggests the way in which British separation was supplemented by restriction of area in quickly welding diverse racial elements, especially in England, into a strong national unit. Egypt, Assyria, Greece, Rome, in fact all the earlier nations of the world benefited in varying degree from the same important asset of compactness in a restricted area. Russia, on the other hand, is a conspicuous example of the weakness resulting from an absence of that quality, since one of the great problems confronting Russian advance, as a nation, is the unification of her diverse human elements into a national whole. The perpetuation of the present lack of unity is directly traceable to the vastness of area and the consequent lack of common contact. Great size may also include, at the outset, such strongly opposed interests as to hinder or seriously endanger temporarily the permanency of national unity. Thus in both the United States and in Australia the question of differences of climate between the warmer and the colder parts of the national territory introduced issues which threatened to split each nation.

The restriction of area which promotes an early development of national unity and strength is likely, however, to become no less a source of weakness in later stages of evolution. The question of making important, or of perpetuating, a nation hinges on the opportunities available for supplying its population with the primary needs of food, clothing and shelter, and whatever may be required in the shape of utensils and mechanical power. Of these, food, clothing, shelter and utensils depend on the soil and materials to be secured from the earth's crust. Mechanical power alone may be derived elsewhere than from the soil or earth's crust, and power plus human direction may to a certain extent be used to purchase the materials of food, clothing and shelter. But since the greater the area the greater are likely to be the opportunities for supplying all these needs directly, size itself, other things being equal, is always a significant measure of relative strength and permanency of national importance. The relative decline of Holland since 1650, from a position near world leadership to a rank far down in the scale of nations, must be attributed largely to the handicap of small size. Though Holland, as a nation, is now probably more prosperous than ever before in its history, its own physical limitations are too great for it to occupy a leading position among nations.

Here again, Britain serves as an instructive example of the variable effect of size at different times in its national life. Profiting materially in its early days from the fact that it was a "tight little island," that very restriction of area and natural opportunity is now forecasting the relative decline of Britain, no less than the same factor did for Holland two centuries ago. Britain contains at present a population of forty millions in an area less than, and not so richly endowed as, that of the three states of Indiana, Illinois and Iowa; a population living in large part through a process of exchange, which now depends on the comparatively limited supply of British coal, about two thirds as great as the amount available in Illinois alone. Unless some substitute power can be found as the coal is exhausted, this basis of exchange will no longer exist, and Britain must look forward to a future in which her population will be limited to the number which her small area can feed, clothe and shelter by direct return from her own soil. Making generous estimate of the possibilities of Britain in these respects, it does not appear that more than 75 per cent. of the area, or less than sixty million acres, are capable of any kind of profitable agricultural development.

At present Italy is practically maintaining a population equal to three fourth that of Great Britain from an area of about fifty million cultivated acres. Italy, however, has superior climatic advantages in her favor and the standard of living of her population would, on the whole, probably seem to the Englishman to be inferior to his own. Hence it appears safe to conclude that the area of Britain, without the equivalent of her present mechanical power, could not at best maintain any more than the existing population. Consequently, as other nations, more richly endowed, continue to increase in numbers and in power, the relative decline of Britain would become inevitable, through the changing value of the physical forces which have shaped her course. What applied to Holland in the seventeenth century applies to Britain to-day, and must eventually apply to all the nations of restricted size and no capability of securing relief through the utilization of larger contiguous areas.

Size, then, has exactly opposed values at the two ends of national evolution. The small size which affords strength to, and hastens the development of, the incipient nation, if unchanged, becomes subsequently the weak spot in the foundation on which it must stand. On the other hand, the size, which through its bigness, is likely to retard early development, may become later a source of tremendous strength. The nation with vast area, though perhaps slower in reaching its full development, has not only the basis for ultimate importance, but also the basis for permanent greatness in so far as anything may be regarded as permanent. Thus by virtue of their respective sizes, and what size means, the future course of the United States, of Russia, or of China, must be radically different from the future of Britain, of Germany or of France. The consideration of the area of a nation, therefore, must be carried further than the usual bare statement of so many square miles, and those who ignore the question of size fail to appreciate one of the most significant items in national evolution and strength.

Surface Configuration.—The configuration of the surface is a controlling factor which should perhaps be considered earlier in the discussion, since it has more or less of a modifying effect on all the preceding factors. It influences climate, favors or hinders the securing of necessities from the soil and the earth's crust, and has much to do with the important question of accessibility, especially by sea. Yet the direct influence of surface configuration by itself on national evolution is, on the whole, less readily traced than in the case of the factors already discussed, for the reason that surfaces practically identical in all important respects may show radically different conditions of development as the result of difference in position, climatic relations and area.

The extremes of configuration, like the extremes of climatic position, are unfavorable to the best national development. Either great diversity, or great monotony of surface are undesirable, but of the two the latter is preferable. Great diversity of surface features, in any except very large areas, may be regarded as the equivalent of prevailing ruggedness, and as a practical barrier to national development on any important scale. The Balkans district of Europe affords the best case in point; a region of decidely irregular contour, it is so completely broken up by more or less effective mountain barriers that ready communication and intimate contact between the people of one part and those of another are not possible. Under such conditions, local interests are greatly magnified, become dominant and the general growth of strong national attributes is unlikely. Great diversity of surface, then, may be said to favor a permanent establishment of the clannish or tribal organization, rather than to promote evolution toward the national state. The effect of surface configuration is shown also in the case of Britain, where the prevailing ruggedness of Scotland and Wales, served, it is true, as a stronghold of defence for refugee natives, but it did not afford the material strength to cope successfully with the more favored and less rugged England. It might even be said that surface features alone made inevitable the domination of all Britain by the people inhabiting the lowlands of England. The combined significance of area and configuration is shown in a contrast of England and Norway, the one, small, moderately diversified, and long important; the other, over twice as large, prevailingly rugged, and never important.

Too great uniformity of surface, amounting to monotony, means little variety of initiative, hence a tendency toward one-sided development. Where variety of surface is lacking, variety of initiative usually depends on one of two factors, first, on the chance location of useful materials in the earth's crust, and second, on sufficient size to produce critical differences in climatic features. In the case of the first factor, however, the discovery and exploitation of the useful materials is, in most cases, distinctly not favored by a uniform surface; and too great contrasts of climate may prove hostile to national solidarity.

When considered from the standpoint of mature nations, however, the extent of the uniform surface is in large degree the measure of national strength and permanence. Irregular or rugged surfaces, as compared with the uniformity of plains, are naturally less heavily cloaked with soil, and lose that soil much more readily if it is disturbed by cultivation. Furthermore, the rugged surface loses a much larger proportion of its total rainfall through run-off, and for that reason shows more quickly the undesirable effects of scanty precipitation. Hence the more uniform surface is more readily adapted to the production of the necessities of life and is at the same time capable of supplying larger quantities for each unit of area. Assuming, therefore, that the ultimate position of a nation depends mainly on its own ability to produce those things which come directly or indirectly from the soil, it may be said that the strength and permanency of a great nation lies mainly in its agricultural plains.

The ideal configuration of surface, judged with respect to the entire question of national evolution, would include enough diversity to stimulate variety in initiative, and at the same time, a sufficient extent of level area, to give permanent strength in supplying the primary wants of a large population. The United States may well be taken as the nearest approach to this ideal configuration. Estimated on this basis, the great nations of the future will be located on, and derive their strength from, the great plains areas of the world. For that reason one great nation may be expected to appear preeminent in the more favorably situated plains of each of the four major continents.

Productivity of the Soil and Climate.—The importance of the productivity of the soil and climate as one of the factors influencing national evolution has already been implied. Its further consideration, however, is necessary in order to indicate its variable application in the different stages of evolution. Meagerness of returns from a fair amount of human effort, or too great productivity with little or no regularity of effort, do not offer the fundamental conditions necessary for the development of nations, as indicated by the fact that no modern nation has risen to importance without having begun on an agricultural basis. No better evidence of that fact can be found than in the case of Britain and Germany, where to-day agriculture is decidedly secondary, but not very long ago was the main source of national strength. Yet however great importance the agricultural basis may be assumed to have as the foundation of national existence, it must be recognized in the study of individual nations, that beyond the early stages of evolution, the course of events, carrying the nation to the highest rank, may for a time reveal no significant control by the productivity of the soil in its own area.

The unrivaled British supremacy, in practically every respect, in the past century, the commercial and industrial conditions of Germany and of Japan at the present time, furnish examples of national development and importance out of proportion, both to the actual use and to the greatest possible productivity of the soil in each of the national areas mentioned. These cases may be taken as typical of a particular stage of development into which some of the nations of to-day have passed naturally, but which the younger nations of the present, as Argentine, Brazil or Canada, can only approach. The stage of development represented by Britain, Germany or Japan depends on the temporary operation of the sixth and seventh physical factors—the possession of potential energy and useful minerals. Later stages, as will be indicated, may very likely bring once more into prominence the influence of the productivity of the soil in the national territory itself.

Potential Energy.—Under the head of potential energy may be grouped all the natural means of developing mechanical power—coal, running water, wind and even the direct rays of the sun. Modern civilization is inseparably associated with the use of two things dependent on potential energy in one form or another: first, the use of heat other than that received direct from the sun; and second, the use of machinery which requires mechanical power either for its making or in its operation. But since heat for any purpose may be secured from mechanical power through the medium of electricity, both needs, for machinery and for heat, hinge on the one question of some single form of potential energy. Coal until recently, at least, has been the one important form of potential energy, for the reason that it furnishes heat directly or supplies power through the medium of steam. These qualities coupled with the possibility of transporting the latent energy to the desired place of utilization, have enabled coal to play perhaps a disproportionate part in directing national development, but its effect may, with some qualification, be taken as indicating the part which mechanical energy, in any form, can play in national evolution.

The value of mechanical power to a nation is best expressed in terms of its equivalent in either animal or man power. One horse power, mechanical energy, may be taken as the equivalent of the power of two average horses or of ten men for a working day of ten hours. A modern steam engine requires not over 2 to 5 pounds of coal for the development of one horse power per hour—a gas engine requires even less—hence a very conservative calculation gives fifty horse power for a working day of ten hours from a single ton of coal. In other words, a ton of coal does in a day the work of at least one hundred horses or of five hundred men. Therefore, one man engaged in mining two tons of coal per day, is producing through the expenditure of one man-power the energy equivalent of a population of 1,000 working men. Calculated on the same basis of values, 80,000 tons of coal produced daily for 300 working days in the year—24,000,000 tons annually—are, in the power they afford, equal to the full energy of a working force greater than the entire population of Britain. The total British coal production at present—290,000,000 tons yearly—consequently represents a working capacity more than ten times that of the whole population in terms of men, while the annual export of coal from Britain is equal to the emigration of ten million laborers.

Every horse power of available mechanical energy, therefore, should be estimated, not simply as a form of power permitting the use of appliances and processes which neither human nor animal energy could make available, but also as so many added members of the population which do not make any increased demands on the soil for food and the materials of clothing or shelter. The possession of this resource in abundance has, in the past, permitted nations to develop at a rate, or to an extent, which bore no relation to their ability to supply locally the necessities of life: the development instead being on a basis of exchanging the products of their mechanical power for the materials of food and clothing. This existence on a basis of exchange, however, involves the operation of two fundamental conditions. First, the important utilization of power does not appear until national development has passed beyond the stage of scanty population, hence it is logically one of the later stages of evolution. Second, the exchange depends on the existence of other national areas still in the early stages of evolution, not taxing their opportunities to their full capacity, and consequently capable of yielding a surplus of the fundamental necessities of life.

Such excessive development through the operation of one physical factor which temporarily overtops all others, as has resulted from the use of coal in Germany, for example, however strong the nation may appear at the time, is not a safe measure of the true strength and permanence of the nation. It may subsequently be greatly reduced by the natural changing of conditions, for unless the nation possesses in itself some ready substitute for coal when its supply is exhausted, as it inevitably will be exhausted comparatively soon for most nations, that nation must look forward to a future in which there are likely to be necessary certain sharp readjustments, with respect to its ability to take care of its own people. Moreover, as the nations now producing a surplus of necessities continue to advance in their own evolution and trend toward the maximum of their own capacity to feed, clothe and shelter a population, other readjustments, of perhaps even more sweeping character, may be necessary in those places where extensive growth has been based primarily on the means of generating mechanical energy. The stage wherein national importance in industry, commerce and population is derived from resources of coal is in any case transitory, and represents only one step in the gradual adjustment of all nations to their physical surroundings.

Water power in abundance, on the contrary, may be regarded as an indication of permanent national importance so far as the advantages derived from mechanical energy are concerned; for the reason that, with intelligent management, the power from running water may be depended on as long as rain continues to fall. Here, however, it is necessary to recall the significance of climatic position, size and surface configuration, since available water power, except in special cases, is the component result of the total quantity of water falling on the land and the proportion of it which runs off through the streams, determined largely by the configuration of the surface. Under the accepted desirable conditions of medium and reliable climatic values, the rainfall on any considerable area would be adequate and sufficiently uniform with respect to the supply in the different seasons of the year. Hence, size of the area and configuration of the surface take on added importance, in that they largely determine the possibilities of water-power development. Both small areas and monotonous uniformity of surface become less desirable, for the reason that in flat regions the fall of the rivers and the condition of their banks do not favor ready or extensive power development; and a small area, whatever its surface, means small actual quantity of water falling on it. Consequently the moderate degree of surface diversity is not simply more desirable through its relation to variety of initiative, but, because of its relation to water power, may be regarded as second in importance only to the conditions permitting agriculture.

For illustration Britain again serves the purpose best, since Britain has for two centuries stood at the forefront of the nations of the world, has developed in a restricted area a large population existing on the basis of exchanging the products of power for the necessities of life, and has, in that development, depended for power almost entirely on a limited supply of coal. Furthermore, Britain is confronted by the realization that the time is not far distant when that coal supply will begin to fail. The question is, therefore, will the small area of Britain with its medium rainfall and moderate diversity of surface offer the means of replacing the steam power now used by power from running water, and through that water power make it possible to maintain, on the existing basis, a population which in the past has increased at the rate of nearly half a million annually? Britain must do that or else be confronted by one of two conditions: either a static population, such as France has exhibited in recent decades; or a declining population due to inability any longer to support the number.

From the standpoint of the power of running water available on the land, the question for Britain probably must be answered in the negative. For example, the average yearly rainfall for Britain, as a whole, is distinctly less than 36 inches; but accepting that figure, for the sake of generosity, and estimating the surface run-off at the high value of

40 per cent. of the total fall, the gross discharge through surface drainage per year from the entire area of Britain is equal only to about one fifth the annual discharge of the Mississippi River system. All of the streams in Britain have the major part of their courses where the land is well under an altitude of 1,000, an elevation less than that of most of the Mississippi drainage basin. In the streams of the latter system the available water power has been estimated to be as high as 25,000,000 horse power. Calculated on the same basis, and in terms of their total discharge, the maximum power capacity of the British streams would not exceed 5,000,000 horse power, which, even if increased by 50 per cent., to give a generous estimate because of the shorter and more rapid descent of some of the British streams, falls far short of meeting the present British needs for mechanical energy. Hence, the dependence of Britain on her streams for power would mean not merely the inability to take care of an increasing population, but also an actual lessening of her ability to support, as at present, the numbers already existing.

This amount of power from streams, however, might be materially supplemented by the utilization of energy in the rise and fall of the ocean waters in the tides, the feasibility of which, under favorable conditions, has already been demonstrated at different places along the coast of this country. Here once more the position of Britain, its size and configuration, are decidedly favorable for the development and general use of such wave and tidal power; practically every locality in the kingdom being so situated as to be able to benefit from its use under the present condition of transmission of power over wires in the form of electricity. Estimates of the extent to which energy of the tides can be utilized for commercial purposes are still largely conjecture, since the need for turning to that source of power has not yet risen, but it seems not unlikely that the future of Britain is to depend, perhaps more closely than ever, on those same physical factors which have been so significant in practically every chapter in the past—her insular position, compactness and configuration of the coast.

Germany, on the other hand, confronted by the same problem of coal exhaustion, has a less hopeful outlook because of her different surroundings. Germany with a large and rapidly increasing population, already grown well beyond the food capacity of the national area, recognizes the necessity for providing for her increasing numbers by increasing commercial and industrial activity—all dependent on mechanical energy. In this respect Germany is less favored than Britain, not only as regards coal,[2] but also as regards water power to replace coal. Calculated on the basis of an average rainfall of 30 inches and a run-off of 40 per cent., both of which figures are high, the total

[2] The actual quantity is estimated to be a little larger in Germany, but so much of it is lignite that it has distinctly less industrial value.

discharge of the German rivers is not above one fourth that of the Mississippi system, as contrasted with one fifth for Britain. Greater ruggedness of surface marks a part of the German territory, but on the other hand, a very large part of the drainage area of the chief streams lies in the North German plain at altitudes under 600 feet, as unfavorable for power development as they have been favorable to river navigation. At the best, therefore, the German streams could hardly be counted on for more than 10,000,000 horse power, or again less than the amount of mechanical energy actually employed at present. The position of Germany offers little prospect for the use of power from the sea on any such important scale as seems feasible in Britain, and other likely sources of water power do not appear to afford the necessary relief. The future of Germany seems, therefore, to present a case in which the question of power and a stage of evolution arising from its use is likely to involve readjustments of a far-reaching character.

The contrast of these two examples, Britain and Germany, may serve to illustrate the extent to which permanent natural sources of mechanical power are factors for national strength, second in importance only to the capacity of the soil to produce food, since under favorable circumstances both afford a solid basis for large national development. It must be recognized, however, that in assuming a logical and permanent stage of evolution based on the possession of power alone, it is necessary to take into account the likelihood of there always being some areas so endowed as to produce surplus necessities of life, while they, or other areas, are unable from their own surroundings to satisfy their needs for the products of power.

Mineral Wealth.—The part played by one sort of mineral supply, in national development, has been indicated in the discussion of coal as a source of energy. With respect to the products of the mines in general and particularly if the term be liberally interpreted, to include all inorganic products of the earth, it may be said that they as a group represent one of the most important of physical factors in the modern progress of nations. Leaving coal entirely aside, it still remains true that the tremendous development of every phase of modern industry, from the cultivation of the soil to the most complex manufacturing process, has become possible only through the constantly increasing employment of mineral products. In fact, the critical difference between the nations of to-day and those of the past is found in the present dependence on materials won from the earth's crust; and it might almost be said that the nations rank to-day and will in the future continue to rank in direct proportion to the wealth of their mineral resources.

The question needs, however, to be considered carefully, since some minerals, popularly accorded great importance, are of distinctly minor significance in their effects on national evolution and strength, and especially since many mineral supplies must be considered as more or less temporary. Gold and silver must be classed among the mineral resources of lesser importance, whatever the merits of their relations to national currency systems, for the reason that they serve man's needs but little when compared with iron, copper or even humble clay products, and consequently their effect on national evolution has been correspondingly less. Gold and silver, it is true, induce men to live where they otherwise would not be found in any large numbers, as in the cold wastes of Alaska and the desert of Australia, but such populations are rarely important or stable. Gold and silver, moreover, when given in exchange, may help to buy necessities for a nation, but all the world's annual output of gold would barely pay for the raw cotton purchased from this country yearly. A nation like Germany, for example, poverty-stricken in its gold and silver deposits, has advanced greatly in every respect in the last forty years despite its necessity of buying food, during the same time that a country like Australia, one of the leading gold localities of the world, has had but unimportant progress. In practically no nation has the possession of the so-called precious metals been a leading, or permanent, determining factor in development.

On the other hand, the use of stone and clay products in providing shelter, and the use of clay or the baser metal products in providing utensils, tools and the like, have lifted a burden from the soil and allowed more of it to be devoted to the production of the materials of food and clothing. They have also at the same time, through their application in machinery, made it possible to produce food and clothing on a far greater scale.

The existing scale of dependence on mineral supplies, however, implies a rate of consumption likely to exhaust any but the richest or most extensive accumulations at no very distant date, considered in terms of historical periods. Hence, once more it appears that restricted area and their limited natural opportunities are of critical significance in the evolution of nations. For such areas as Britain and Germany, already populated to the limit of soil capacity, with little prospect of expanding their power resources, and not over-stocked with supplies of the minerals which are essential to so many branches of industry, the future holds little or no prospect for further sound national growth. Such nations are to be regarded as having reached practically the culminating point in their evolution, with their future likely to be marked by the gradual adjustment of economic conditions to the permanent opportunities for supporting a population.

Conclusions.—It appears, therefore, that three general conclusions may be drawn from this discussion. First, each nation should be regarded as following a regular life course of definite ages, in which it is influenced at all times by the combined effect of the geographical factors of its environment. Second, from the proper valuation of these controlling factors it is possible in any stage of evolution to measure the real strength of a nation. Finally, every nation will arrive eventually at a stage where its physical surroundings set a limit to further development, materially, though not necessarily in culture. It may be expected that each nation as it arrives at this later stage in its existence will exhibit the spectacle of a static population, and such a nation may be said to have attained its full maturity—that is a condition of practically perfect adjustment between national opportunity and national development. France may be taken as an example of a nation which has reached, earlier than any of the others, this stage of full maturity.

It may even be that in individual cases, as perhaps in Germany and Japan, the temporary operation of one or two factors, as coal and some useful minerals, have already induced a condition of development which will necessitate subsequent readjustments, even to the point of actual decadence. A parallel condition might also arise through the misuse and consequent destruction of those national opportunities which should be permanent, as through soil erosion and the destruction of water power by deforestation. Wherever, by one means or the other, the basis for maintaining the national existence is materially lessened or destroyed, the nation must be regarded as old, or physically decadent, having exhausted the forces with which it was naturally endowed, just as in the old age of the human being, it is the breaking down of the individual physical endowment which marks the decline.

This inevitable adjustment of the nations of the world to their environments seems to call for relative decadence, like that of Holland since 1650, on the part of many nations holding a more or less prominent place to-day, especially so in the case of those of small area and restricted opportunity: and a corresponding rise, both relative and absolute, in most of the large units, which, in most cases, are still in the early, or young stages of their national evolution. In this latter group Russia, perhaps, is the most striking example, while the United States is somewhat farther along toward the stage of maturity: it might be described as having passed its adolescence and beginning to feel its strength, while Russia has still to reach the adolescent stage of youth. Thus the great nation of to-day may in one case be the great nation of to-morrow; in another case not. The real measure of fitness lies in the relation of each individual nation to the physical factors by which its evolution and its strength are determined.

THE DYNAMICS OF A GOLF BALL[1]

By Sir J. J. Thomson

CAVENDISH PROFESSOR OF EXPERIMENTAL PHYSICS, UNIVERSITY OF CAMBRIDGE, PROFESSOR OF NATURAL PHILOSOPHY, ROYAL INSTITUTION

THERE are so many dynamical problems connected with golf that a discussion of the whole of them would occupy far more time than is at my disposal this evening. I shall not attempt to deal with the many important questions which arise when we consider the impact of the club with the ball, but confine myself to the consideration of the flight of the ball after it has left the club. This problem is in any case a very interesting one, it would be even more interesting if we could accept the explanations of the behavior of the ball given by many contributors to the very voluminous literature which has collected round the game; if these were correct, I should have to bring before you this evening a new dynamics, and announce that matter when made up into golf balls obeys laws of an entirely different character from those governing its action when in any other condition.

If we could send off the ball from the club, as we might from a catapult, without spin, its behavior would be regular, but uninteresting; in the absence of wind its path would keep in a vertical plane, it would not deviate either to the right or to the left, and would fall to the ground after a comparatively short carry.

But a golf ball when it leaves the club is only in rare cases devoid of spin, and it is spin which gives the interest, variety and vivacity to the flight of the ball. It is spin which accounts for the behavior of a sliced or pulled ball, it is spin which makes the ball soar or "douk," or execute those wild flourishes which give the impression that the ball is endowed with an artistic temperament, and performs these eccentricities as an acrobat might throw in an extra somersault or two for the fun of the thing. This view, however, gives an entirely wrong impression of the temperament of a golf ball, which is in reality the most prosaic of things, knowing while in the air only one rule of conduct, which it obeys with unintelligent conscientiousness, that of always following its nose. This rule is the key to the behavior of all balls when in the air, whether they are golf balls, base balls, cricket balls or tennis balls. Let us, before entering into the reason for this rule, trace out some of its consequences. By the nose of the ball we mean the point on the ball furthest in front.

[1] A lecture given before the Royal Institution of Great Britain.

Thus if, as in Fig. 1, C the center of the ball is moving horizontally to the right, A will be the nose of the ball; if it is moving horizontally to the left, B will be the nose. If it is moving in an inclined direction CP, as in Fig. 2, then A will be the nose.

Now let the ball have a spin on it about a horizontal axis, and suppose the ball is travelling horizontally, as in Fig. 3, and that the

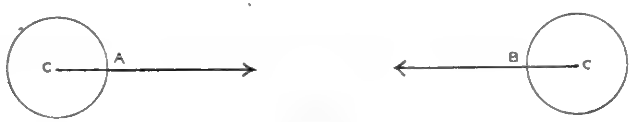


FIG. 1.

direction of the spin is as in the figure, then the nose A of the ball is moving upwards, and since by our rule the ball tries to follow its nose, the ball will rise and the path of the ball will be curved as in the dotted line. If the spin on the ball, still about a horizontal axis, were in the opposite direction, as in Fig. 4, then the nose A, of the ball, would be moving downwards, and as the ball tries to follow its

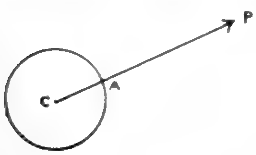


FIG. 2.

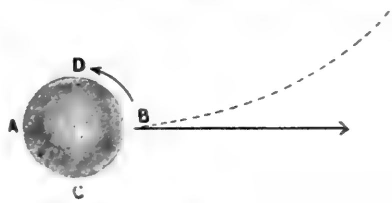


FIG. 3.

nose it will duck downwards, and its path will be like the dotted line in Fig. 4.

Let us now suppose that the ball is spinning about a vertical axis, then if the spin is as in Fig. 5, as we look along the direction of the flight of the ball the nose is moving to the right; hence by our rule the ball will move off to the right, and its path will resemble the dotted

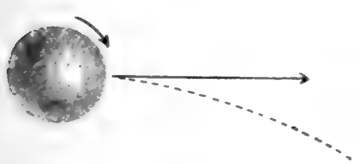


FIG. 4.

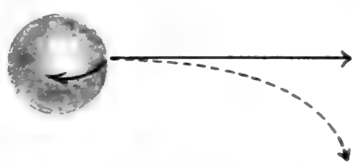


FIG. 5.

line in Fig. 5, in fact, the ball will behave like a sliced ball. Such a ball, as a matter of fact, has spin of this kind about a vertical axis.

If the ball spins about a vertical axis in the opposite direction as in Fig. 6, then, looking along the line of flight, the nose is moving to the left, hence the ball moves off to the left, describing the path indicated by the dotted line; this is the spin possessed by a "pulled" ball.

If the ball were spinning about an axis along the line of flight, the axis of spin would pass through the nose of the ball, and the spin would not affect the motion of the nose; the ball following its nose would thus move on without deviation.

FIG. 6.

Thus, if a cricket ball were spinning about an axis parallel to the line joining the wickets, it would not swerve in the air, it would, however, break in one way or the other after striking the ground; if, on the other hand, the ball were spinning about a vertical axis, it would swerve while in the air, but would not break on hitting the ground. If the ball were spinning about an axis intermediate between these directions it would both swerve and break.

Excellent examples of the effect of spin on the flight of a ball in the air are afforded in the game of base ball; an expert pitcher by putting on the appropriate spins can make the ball curve either to the right or to the left, upwards or downwards; for the sideway curves the spin must be about a vertical axis, for the upward or downward ones about a horizontal axis.

A lawn-tennis player avails himself of the effect of spin when he puts "top spin" on his drives, *i. e.*, hits the ball on the top so as to make it spin about a horizontal axis, the nose of the ball traveling downwards, as in Fig. 4; this makes the ball fall more quickly than it otherwise would, and thus tends to prevent it going out of the court.

Before proceeding to the explanation of this effect of spin I will show some experiments which illustrate the point we are considering. As the forces acting on the ball depend on the *relative* motion of the ball and the air, they will not be altered by superposing the same velocity on the air and the ball; thus, suppose the ball is rushing forward through the air with the velocity V, the forces will be the same if we superpose on both air and ball a velocity equal and opposite to that of the ball; the effect of this is to reduce the center of the ball to rest, but to make the air rush past the ball as a wind moving with the velocity V. Thus, the forces are the same when the ball is moving and the air at rest, or when the ball is at rest and the air moving. In lecture experiments it is not convenient to have the ball flying about the room, it is much more convenient to keep the ball still and make the air move.

The first experiment I shall try is one made by Magnus in 1852; its object is to show that a rotating body moving relatively to the air is acted on by a force in the direction in which the nose of the body is moving relatively to its center; the direction of this force is thus at right angles, both to the direction in which the center of the body is moving, and also to the axis about which the body is spinning.

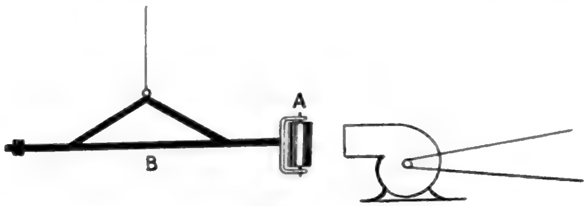


FIG. 7.

For this purpose a cylinder *A* (Fig. 7) is mounted on bearings so that it can be spun rapidly about a vertical axis; the cylinder is attached to one end of the beam *B*, which is weighted at the other end, so that when the beam is suspended by a wire it takes up a horizontal position. The beam yields readily to any horizontal force, so that if the cylinder is acted on by such a force, this will be indicated by the motion of the beam. In front of the cylinder there is a pipe *D*, through which a rotating fan driven by an electric motor sends a blast of air which can be directed against the cylinder. I adjust the beam and the beam carrying the cylinder, so that the blast of air strikes the cylinder symmetrically; in this case, when the cylinder is not rotating the impact against it of the stream of air does not give rise to any motion of the beam. I now spin the cylinder, and you see that when

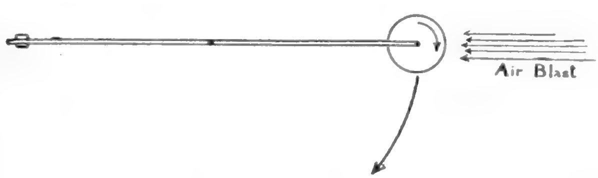


FIG. 8.

the blast strikes against it the beam moves off sideways. It goes off one way when the spin is in one direction, and in the opposite way when the direction of spin is reversed. The beam, as you will see, rotates in the same direction as the cylinder, which an inspection of Fig. 8 will show you is just what it would do if the cylinder were acted upon by a force in the direction in which its nose (which, in this case, is the point on the cylinder first struck by the blast) is moving. If I stop the blast, the beam does not move even though I spin the cylinder, nor does it move when the blast is in action if the rotation of the cylinder is stopped; thus both spin of the cylinder and movement of it through the air are required to develop the force on the cylinder.

Another way of showing the existence of this force is to take a pendulum whose bob is a cylinder, or some other symmetrical body, mounted so that it can be set in rapid rotation about a vertical axis. When the bob of the pendulum is not spinning the pendulum keeps swinging in one plane, but when the bob is set spinning the plane in which the pendulum swings no longer remains stationary, but rotates slowly in the same sense as the bob is spinning (Fig. 9).

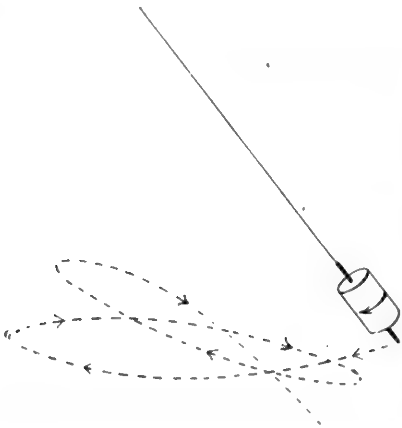


Fig. 9.

We shall now pass on to the consideration of how these forces arise. They arise because when a rotating body is moving through the air the pressure of the air on one side of the body is not the same as that on the other: the pressures on the two sides do not balance, and thus the body is pushed away from the side where the pressure is greatest.

Thus, when a golf ball is moving through the air, spinning in the direction shown in Fig. 10, the pressure on the side *ABC*, where the velocity due to the spin conspires with that of translation, is greater than that on the side *ADB*, where the velocity due to the spin is in the opposite direction to that due to the translatory motion of the ball through the air.

I will now try to show you an experiment which proves that this is the case, and also that the difference between the pressure on the two sides of the golf ball depends upon the roughness of the ball.

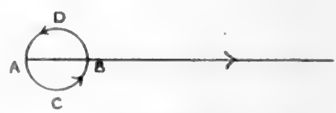


Fig. 10.

In this instrument, Fig. 11, two golf balls, one smooth and the other having the ordinary bramble markings, are mounted on an axis, and can be set in rapid rotation by an electric motor. An air-blast produced by a fan comes through the pipe *B*, and can be directed against the balls; the instrument is provided with an arrangement by which the supports of the axis carrying the balls can be raised or lowered so as to bring either the smooth or the bramble-marked ball opposite to the blast. The pressure is measured in the following way: *LM* are two tubes connected with the pressure-gauge *PQ*; *L* and *M* are placed so that the golf balls can just fit in between them; if the pressure of the air on the side *M* of the balls is greater than that of the side *L* the liquid on the right-hand side *Q* of the pressure-gauge will be depressed; if, on the other hand, the pressure at *L* is greater than that at *M* the left-hand side *P* of the gauge will be depressed.

I first show that when the golf balls are not rotating there is no difference in the pressure on the two sides when the blast is directed

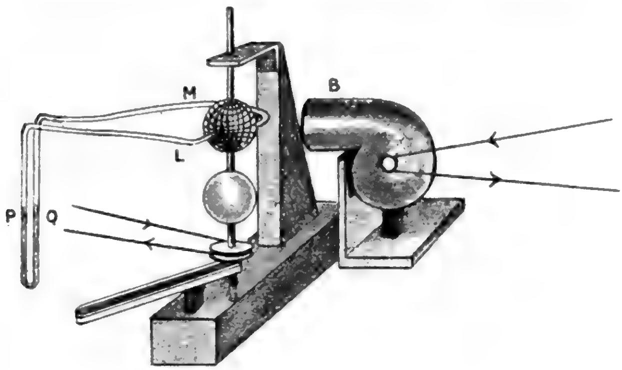


FIG. 11.

against the balls; you see there is no motion of the liquid in the gauge. Next I stop the blast and make the golf balls rotate; again there is no motion in the gauge. Now when the golf balls are spinning in the direction indicated in Fig. 11, I turn on the blast, the liquid falls on the side *Q* of the gauge, rises on the other side. Now I reverse the direction of rotation of the balls, and you see the motion of the liquid in the gauge is reversed, indicating that the high pressure has gone from one side to the other. You see that the pressure is higher on the side *M* where the spin carries this side of the ball into the blast, than on *L* where the spin tends to carry the ball away from the blast. If we could imagine ourselves on the golf ball, the wind would be stronger on the side *M* than on *L*, and it is on the side of the strong wind that the pressure is greatest. The case when the ball is still and the air moving from right to left is the same from the dynamical point of view as when the air is still and the ball moves from left to right; hence we see that the pressure is greatest on the side where the spin makes the velocity through the air greater than it would be without spin.

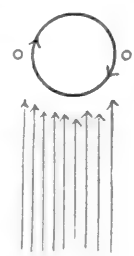


FIG. 12.

Thus, if the golf ball is moving, as in Fig. 12, the spin increases the pressure on the right of the ball, and diminishes the pressure on the left.

To show the difference between the smooth ball and the rough one, I bring the smooth ball opposite the blast; you observe the difference between the levels of the liquid in the two arms of the gauge. I now move the rough ball into the place previously occupied by the smooth one, and you see that the difference of the levels is more than doubled, showing that with the same spin and speed of air blast the difference of pressure for the rough ball is more than twice that for the smooth.

We must now go on to consider why the pressure of the air on the two sides of the rotating ball should be different. The gist of the explanation was given by Newton nearly 250 years ago. Writing to Oldenburg in 1671 about the dispersion of light, he says, in the course of his letter, "I remembered that I had often seen a tennis-ball struck with an oblique racket describe such a curved line. For a circular as well as progressive motion being communicated to it by that stroke, its parts on that side where the motions conspire must press and beat the contiguous air more violently, and there excite a reluctancy and reaction of the air proportionately greater." This letter has more than a scientific interest—it shows that Newton set an excellent precedent to succeeding mathematicians and physicists by taking an interest in games. The same explanation was given by Magnus, and the mathematical theory of the effect is given by Lord Rayleigh in his paper on "The Irregular Flight of a Tennis Ball," published in the *Messenger of Mathematics,* Vol. VI., p. 14, 1877. Lord Rayleigh shows that the force on the ball resulting from this pressure difference is at right angles to the direction of motion of the ball, and also to the axis of spin, and that the magnitude of the force is proportioned to the velocity of the ball multiplied by the velocity of spin, multiplied by the sine of the angle between the direction of motion of the ball and the axis of spin. The analytical investigation of the effects which a force of this type would produce on the movement of a golf ball has been discussed very freely by Professor Tait, who also made a very interesting series of experiments on the velocities and spin of golf balls when driven from the tee and the resistance they experience when moving through the air.

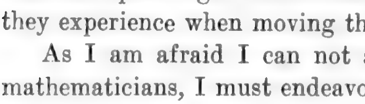


FIG. 13.

As I am afraid I can not assume that all my hearers are expert mathematicians, I must endeavor to give a general explanation without using symbols, of how this difference of pressure is established.

Let us consider a golf ball, Fig. 13, rotating in a current of air flowing past it. The air on the lower side of the ball will have its motion checked by the rotation of the ball, and will thus in the neighborhood of the ball move more slowly than it would do if there were no golf ball present, or than it would do if the golf ball were there but was not spinning. Thus if we consider a stream of air flowing along the channel *PQ,* its velocity when near the ball at *Q* must be less than its velocity when it started at P; there must, then, have been pressure acting against the motion of the air as it moved from P to Q, *i. e.*, the pressure of the air at Q must be greater than at a place like P, which is some distance from the ball. Now let us consider the other side of the ball: here the spin tends to carry the ball in the direction of the blast of air; if the velocity of the surface of the ball is greater than that of the blast, the ball will increase the velocity of the blast on this side, and if the velocity of the ball is less than that of the blast, though it will diminish the velocity of the air, it will not do so to so great an extent as on the other side of the ball. Thus the increase in pressure of the air at the top of the ball over that at P, if it exists at all, will be less than the increase in pressure at the bottom of the ball. Thus the pressure at the bottom of the ball will be greater than that at the top, so that the ball will be acted on by a force tending to make it move upwards.

We have supposed here that the golf ball is at rest, and the air rushing past it from right to left; the forces are just the same as if the air were at rest, and the golf ball rushing through it from left to right. As in Fig. 13, such a ball rotating in the direction shown in the figure will move upwards, *i. e.*, it will follow its nose.

It may perhaps make the explanation of this difference of pressure easier if we take a somewhat commonplace example of a similar effect. Instead of a golf ball, let us consider the case of an Atlantic liner, and, to imitate the rotation of the ball, let us suppose that the passengers are taking their morning walk on the promenade deck, all circulating round the same way. When they are on one side of the boat they have to face the wind, on the other side they have the wind at their backs. Now when they face the wind, the pressure of the wind against them is greater than if they were at rest, and this increased pressure is exerted in all directions, and so acts against the part of the ship adjacent to the deck; when they are moving with their backs to the wind, the pressure against their backs is not so great as when they were still, so the pressure acting against this side of the ship will not be so great. Thus the rotation of the passengers will increase the pressure on the side of the ship when they are facing the wind, and diminish it on the other side. This case is quite analogous to that of the golf ball.

The difference between the pressures on the two sides of the golf ball is proportional to the velocity of the ball multiplied by the velocity of spin. As the spin imparted to the ball by a club with a given loft is proportional to the velocity with which the ball leaves the club; the difference of pressure when the ball starts is proportional to the square of its initial velocity. The difference between the average pressures on the two sides of the ball need only be about one fifth of one per cent. of the atmospheric pressure to produce a force on the ball greater than its weight. The ball leaves the club in a good drive with a velocity sufficient to produce far greater pressures than this. The consequence is that when the ball starts from the tee spinning in the direction shown in Fig. 14, this is often called underspin, the upward force due to the spin is greater than its weight, thus the resultant force is upwards, and the ball is repelled from the earth instead of being attracted to it. The consequence is that the path of the ball curves upward, as in the curve *A*, instead of downwards, as in *B*, which would be its path if it had no spin. The spinning golf ball is in fact a very efficient heavier than air flying machine, the lifting force may be many times the weight of the ball.

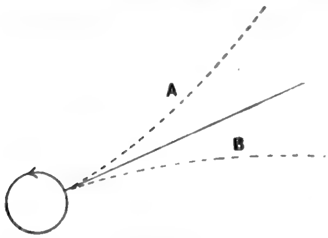


Fig. 14.

The path of the golf ball takes very many interesting forms as the amount of spin changes. We can trace all these changes in the arrangement which I have here, and which I might call an electric golf links. With this apparatus I can subject small particles to forces of exactly the same type as those which act on a spinning golf ball.

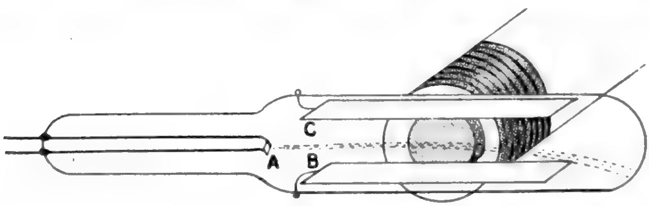


Fig. 15.

These particles start from what may be called the tee *A* (Fig. 15). This is a red hot piece of platinum with a spot of barium oxide upon it, the platinum is connected with an electric battery which causes negatively electrified particles to fly off the barium and travel down the glass tube in which the platinum strip is contained; nearly all the air has been exhausted from this tube. These particles are luminous, so that the path they take is very easily observed. We have now got our golf balls off from the tee, we must now introduce a vertical force to act upon them to correspond to the force of gravity on the golf ball. This is easily done by the horizontal plates *BC*, which are electrified by connecting them with an electric battery; the upper one is electrified negatively, hence when one of these particles moves between the plates it is exposed to a constant downwards force, quite analogous to the weight of the ball. You see now when the particles pass between the plates their path has the shape shown in Fig. 16;

this is the path of a ball without spin. I can imitate the effect of spin by exposing the particles while they are moving to magnetic force, for the theory of these particles shows that when a magnetic force acts upon them, it produces a mechanical force which is at right angles to the direction of motion of the particles, at right angles also to the magnetic force and proportional to the product of the

Fig. 16.

velocity of the particles, the magnetic force and the sine of the angle between them. We have seen that the force acting on the golf ball is at right angles to the direction in which it is moving at right angles to the axis of spin, and proportional to the product of the velocity of the ball, the velocity of spin and the sine of the angle between the velocity and the axis of spin. Comparing these statements you will see that the force on the particle is of the same type as that on the golf

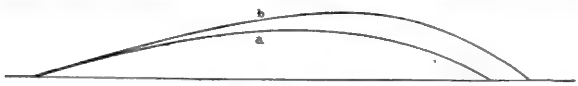


Fig. 17.

ball if the direction of the magnetic force is along the axis of spin and the magnitude of the force proportional to the velocity of spin, and thus if we watch the behavior of these particles when under the magnetic force we shall get an indication of the behavior of the spinning golf ball. Let us first consider the effect of underspin on

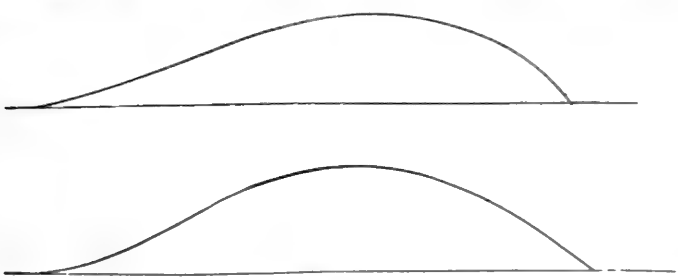


Fig. 18.

the flight of the ball: in this case the ball is spinning, as in Fig. 3, about a horizontal axis at right angles to the direction of flight. To imitate this spin I must apply a horizontal magnetic force at right angles to the direction of flight of the particles. I can do this by means of the electromagnet. I will begin with a weak magnetic force, representing a small spin. You see how the path differs from the one when there was no magnetic force; the path, to begin with, is flatter though still concave, and the carry is greater than before—see Fig. 17, *a*. I now increase the strength of the magnetic field, and you will see that the carry is still further increased, Fig. 17, *b*. I increase the spin still further, and the initial path becomes convex instead of

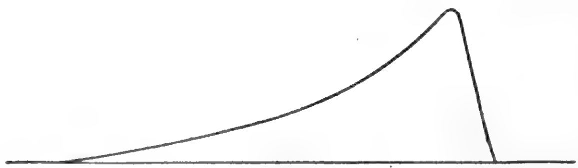


FIG. 19.

concave, with a still further increase in carry, Fig. 18. Increasing the force still more, you see the particle soars to a great height, then comes suddenly down, the carry now being less than in the previous case (Fig. 19). This is still a familiar type of the path of the golf ball. I now increase the magnetic force still further, and now we get a type

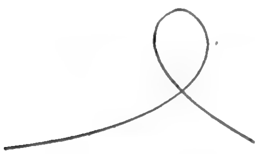


FIG. 20.

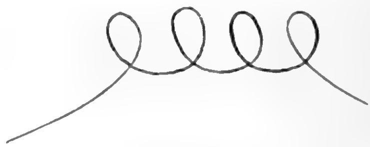


FIG. 21.

of flight not to my knowledge ever observed in a golf ball, but which would be produced if we could put on more spin than we are able to do at present. You see there is a kink in the curve, and at one part of the path the particle is actually traveling backwards (Fig. 20). Increasing the magnetic force I get more kinks, and we have a type

FIG. 22.

of drive which we have to leave to future generations of golfers to realize (Fig. 21).

By increasing the strength of the magnetic field I can make the curvature so great that the particles fly back behind the tee, as in Fig. 22.

So far I have been considering underspin. Let us now illustrate slicing and pulling; in these cases the ball is spinning about a vertical axis. I must therefore move my electromagnet, and place it so that it produces a vertical magnetic force (Fig. 23). I make the force act

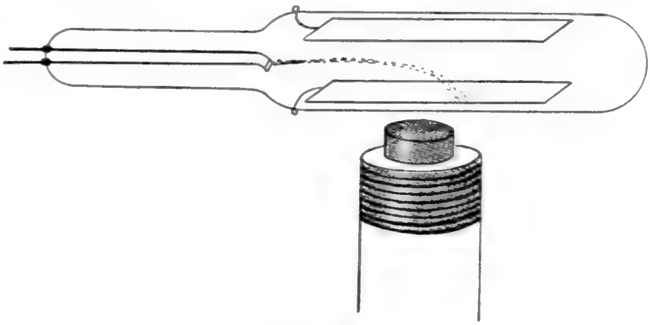


Fig. 23.

one way, say downwards, and you see the particles curve away to the right, behaving like a sliced ball. I reverse the direction of the force and make it act upwards, and the particles curve away to the left, just like a pulled ball.

By increasing the magnetic force we can get slices and pulls much more exuberant than even the worst we perpetrate on the links.

Though the kinks shown in Fig. 20 have never, as far as I am aware, been observed on a golf links, it is quite easy to produce them if we use very light balls. I have here a ball *A* made of very thin india-rubber of the kind used for toy balloons, filled with air, and weighing very little more than the air it displaces; on striking this

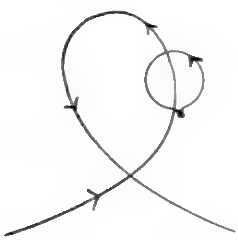


Fig. 24.

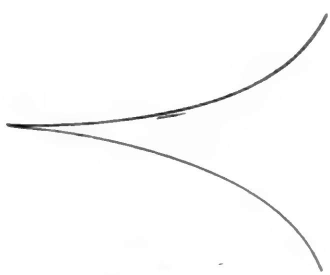


Fig. 25.

with the hand, so as to put underspin upon it, you see that it describes a loop, as in Fig. 24.

Striking the ball so as to make it spin about a vertical axis, you see that it moves off with a most exaggerated slice when its nose is moving to the right looking at it from the tee, and with an equally pronounced pull when its nose is moving to the left.

One very familiar property of slicing and pulling is that the curvature due to them becomes much more pronounced when the velocity of the ball has been reduced, than it was at the beginning when the velocity was greatest. We can easily understand why this should be so if we consider the effect on the sideways motion of reducing the velocity to one half. Suppose a ball is projected from *A* in the direction *AB,* but is sliced; let us find the sideways motion *BC* due to slice. The sideways force is, as we have seen, proportional to the product of the velocity of the ball and the velocity of spin, or if we keep the spin the same in the two cases, to the velocity of the ball; hence, if we halve the velocity we halve the sideways force, hence, in the same time the displacement would be halved too, but when the velocity is halved the time taken for the ball to pass from *A* to *B* is doubled. Now the displacement produced by a constant force is proportional to the square of the time; hence, if the force had remained constant, the sideways deflection *BC* would have been increased four times by halving the velocity, but as halving the

FIG. 26.

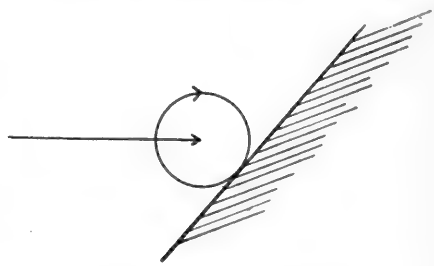


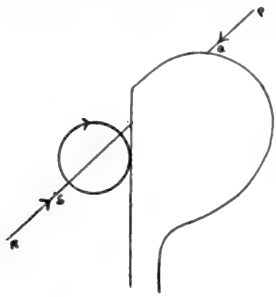
FIG. 27.

velocity halves the force, *BC* is doubled when the velocity is halved; thus the sideways movement is twice as great when the velocity is halved.

If the velocity of spin diminished as rapidly as that of translation the curvature would not increase as the velocity diminished, but the resistance of the air has more effect on the speed of the ball than on its spin, so that the speed falls the more rapidly of the two.

The general effect of wind upon the motion of a spinning ball can easily be deduced from the principles we discussed in the earlier part of the lecture. Take, first, the case of a head-wind. This wind increases the relative velocity of the ball with respect to the air; since the force due to the spin is proportional to this velocity, the wind increases this force, so that the effects due to spin are more pronounced when there is a head-wind than on a calm day. All golfers must have had had only too many opportunities of noticing this. Another illustration is found in cricket; many bowlers are able to swerve when bowling against the wind who can not do so to any considerable extent on a calm day.

Let us now consider the effect of a cross-wind. Suppose the wind is blowing from left to right, then, if the ball is pulled, it will be rotating in the direction shown in Fig. 26; the rules we found for the effect of rotation on the difference of pressure on the two sides of a ball in a blast of air show that in this case the pressure on the front half of the ball will be greater than that on the rear half, and thus tend to stop the flight of the ball. If, however, the spin was



28.

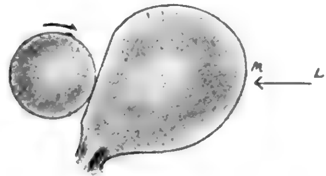


FIG. 29.

that for a slice, the pressure on the rear half would be greater than the pressure in front, so that the difference in pressure would tend to push on the ball and make it travel further than it otherwise would. The moral of this is that if the wind is coming from the left we should play up into the wind and slice the ball, while if it is coming from the right we should play up into it and pull the ball.

I have not time for more than a few words as to how the ball acquires the spin from the club. But if you grasp the principle that the

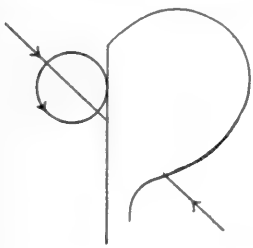


FIG. 30.

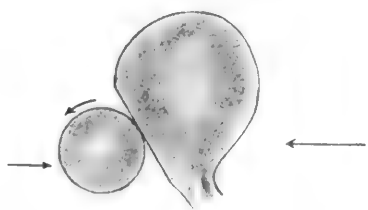


FIG. 31.

action between the club and the ball depends only on their *relative* motion, and that it is the same whether we have the ball fixed and move the club, or have the club fixed and project the ball against it, the main features are very easily understood.

Suppose Fig. 27 represents the section of the head of a lofted club moving horizontally forward from right to left, the effect of the impact will be the same as if the club were at rest and the ball were shot against it horizontally from left to right. Evidently, however, in this case the ball would tend to roll up the face, and would thus get spin about a horizontal axis in the direction shown in the figure; this is underspin, and produces the upward force which tends to increase the carry of the ball.

Suppose, now, the face of the club is not square to its direction of motion, but that looking down on the club its line of motion when it strikes the ball is along *PQ* (Fig. 28), such a motion as would be produced if the arms were pulled in at the end of the stroke, the effect of the impact now will be the same as if the club were at rest and the ball projected along *RS*, the ball will endeavor to roll along the face away from the striker; it will spin in the direction shown in the figure about a vertical axis. This, as we have seen, is the spin which produces a slice. The same spin would be produced if the motion of the club were along *LM* and the face turned so as to be in the position shown in Fig. 29, *i. e.*, with the heel in front of the toe.

If the motion and position of the club were as in Figs. 30 and 31, instead of as in Figs. 28 and 29, the same consideration would show that the spin would be that possessed by a pulled ball.

THE PROGRESS OF SCIENCE

SCIENTIFIC MEETINGS AT MINNEAPOLIS AND ELSEWHERE

The convocation week meeting of the American Association for the Advancement of Science and the affiliated scientific societies was held this year at Minneapolis beginning on the evening of December 27. The attendance of scientific men was in the neighborhood of 1,200, which is about half as large as at the recent meetings in eastern cities. Although the number of men of science in the central states is continually increasing, and the center of scientific population will soon coincide with the center of the general population, Minneapolis is in the far northwest of the region, and it is a considerable railway journey from the seats of other universities. It is well known that the distance from the east to the west is psychologically longer than the reverse. There were at Minneapolis about a hundred scientific men from the eastern seaboard.

The chemists had as usual the largest attendance and the most extensive program. Next came the zoologists and botanists. The geologists had a competing meeting elsewhere; the anthropologists did not meet, and the section of social and economic science had a very small attendance. The national societies devoted to these subjects and to engineering do not meet with the association and it is difficult to decide what should be done in such cases. Probably the best solution is to have no program of special papers, but to plan one or two sessions of general interest, such as the papers on aviation arranged this year by the officers of the section of mechanical science and engineering.

The number of papers on the program to be presented before each section of the association or the corresponding affiliated societies was as follows:

Mathematics and astronomy	34
Physics	40
Chemistry	178
Mechanical science and engineering	21
Geology and geography	24
Zoology	122
Botany	81
Anthropology and psychology	41
Social and economic science	8
Physiology and experimental medicine	13
Education	30
Total	592

At the opening session the retiring president, Dr. David Starr Jordan—distinguished equally as a zoologist, a university president, an advocate of peace and in other good causes—after introducing the president of the meeting, Professor A. A. Michelson, of the University of Chicago—one of the most eminent of living men of science—gave his address, entitled "The Making of a Darwin." Dr. Jordan argued that the fundamental elements in the making of an investigator are the original material, to which we may look to heredity alone; meeting nature at first hand and meeting her early and persistently, and the personal inspiration and enthusiasm derived from some great teacher. It was refreshing to hear a university president characterize at their true value the machinery and paraphernalia of the modern university. Perhaps the address was not so judicial as might have been expected in view of the double office held by the speaker, but it was none the less interesting on that account. The group of zoologists drawn to the Johns Hopkins

DR. CHARLES E. BESSEY,
President of the American Association for the Advancement of Science.

University in its earlier years largely by fellowships and using laboratory methods of investigation will bear comparison better than Dr. Jordan seems to think with the earlier group of naturalists of the school of Agassiz.

The addresses of the vice-presidents of the association maintained high standards and were in most cases of general interest. Thus Professor Minot, of Harvard, treated the method of science; Professor Brown, of Yale, the relation of Jupiter with the asteroids; Dr. Bauer, of the Carnegie Institution, research in terrestrial magnetism; Professor McPherson, of Ohio State University, the production of carbohydrates in plants; Director Brock, of the Canadian Geological Survey, northern Canada, and Professor Ritter, of the University of California, mechanism and vitalism. The addresses before the special societies and the discussions and papers of more than ordinary interest can not even be mentioned by title in a short note.

Dr. Charles E. Bessey, professor of botany at the University of Nebraska, dean and on several occasions acting president, distinguished for his contributions to science and for establishing in a western university a center of botanical teaching and research whose influence has extended over the whole country, was elected president of the American Association to preside over the meeting to begin at Washington on December 27, 1911.

While the American Association and a large group of national scientific societies were meeting at Minneapolis, other societies were meeting elsewhere. At Ithaca the American Society of Naturalists under the presidency of Dr. D. T. MacDougal had an interesting program devoted to problems of experimental evolution. With them met the eastern zoologists and the bacteriologists. The geologists, geographers and paleontologists met in Pittsburgh, the physiologists at New Haven, the mathematicians in New York and the anthropologists in Providence. There are scientific and social advantages both in a large convocation-week gathering of all men of science and in smaller meetings of groups devoted to a single science. Probably the best results are obtained by adopting different plans on different occasions.

THE UNIVERSITY OF MINNESOTA

There are at least three objects attained by attendance at scientific meetings. The papers and discussions are the official occasion, and are certainly of importance. They exhibit contemporary and common interests in a way that is not otherwise possible, and they often serve as a stimulus to research work both before and after the meeting. Of scarcely less consequence are the personal acquaintances and renewed friendships. The third advantage of migratory meetings is the opportunity to visit different parts of the country and to see their scientific and educational institutions. The more distant the place of meeting, the more interesting they are likely to be. So men of science are repaid for their journeys in direct proportion to their length.

A long trip would be well rewarded by the opportunity to see the University of Minnesota. The development of our state universities is probably the most significant movement in higher education, and nowhere are the opportunities and problems exhibited on a more comprehensive scale than in Minnesota. The adjacent states of Michigan, Illinois, Wisconsin and Minnesota possess four of our greatest universities. For many years Michigan led the way; more recently Wisconsin has made the most rapid advances, both in the standards reached in its faculties and in its influence in the state. Illinois and Minnesota, established later, are now likely to press forward in friendly rivalry for leadership. The state of Illinois has two private universities—one of them

FOLWELL HALL, THE COLLEGE BUILDING.

rivaling Harvard and Columbia in its endowments and standards—which will continue to share with the state institution the educational leadership of the state. Minnesota has no competition; and its situation in a large city and adjacent to the capital of the state gives it certain advantages, especially for its professional schools. It has been more fortunate than other state universities in retaining possession of its land grants and in finding them to be the site of vast mineral resources. Most of all it is happy in the possession of a population of high character and intelligence.

Historians are likely to describe the epochs of a country's history under the reigning sovereigns, whether these personages have played a significant or an insignificant part in its affairs. Universities are in like manner known by the administrations of their successive presidents.

Dr. W. W. Folwell was in charge during the infancy of the University of Minnesota, from 1869 to 1884. Dr. Cyrus Northrop has in truly patriarchal fashion guided its vigorous youth. Almost his last official act was to welcome the scientific societies to Minneapolis. Dr. G. E. Vincent, professor of sociology in the University of Chicago, active in its educational management and in the Chautauqua movement inaugurated by his father, now assumes the presidency. It is difficult to exaggerate the possibilities of the development of the university during his administration.

All the buildings now on the campus have been erected within the past twenty-five years. In spite of or on account of their varying and somewhat naïve styles of architecture they make a pleasing impression. Folwell Hall, the headquarters for the scientific societies, is a building admirably constructed for class work. Chemistry, physics and the natural sciences have satisfactory buildings, though it is planned to replace or alter them. Extensive groups of buildings are to be erected for the engineering and medical departments. The university has not as yet made use of its posi-

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Main Building of the School of Agriculture.

tion on a bluff overlooking the Mississippi, but plans have been drawn to remodel the entire arrangement of the buildings with a view to taking advantage of its fine site.

Land, buildings and equipment, students and teachers in large numbers, the university will surely have. It is now a big university and will become much bigger. Whether it will become one of the great universities of the world will depend on whether it can find great men for its chairs. This is the question before all our universities: it should be the dominant concern of Minnesota at the present time.

SCIENTIFIC ITEMS

Presidents of the national scientific societies have been elected as follows: The American Society of Naturalists, Professor H. S. Jennings, of the Johns Hopkins University; The American Chemical Society, Professor Alexander Smith, of the University of Chicago; The Botanical Society of America, Professor W. G. Farlow, of Harvard University; The Geological Society of America, Professor W. M. Davis, of Harvard University; The Association of American Geographers, Professor Ralph S. Tarr, of Cornell University; The American Paleontological Society, Professor William B. Scott, of Princeton University; The Society of Biological Chemists, Professor L. B. Mendel, of Yale University; The American Anthropological Association, Dr. J. Walter Fewkes, of the Bureau of American Ethnology; The American Psychological Association, Professor C. E. Seashore, University of Iowa; the American Philosophical Association, Professor Frederick J. E. Woodbridge, of Columbia University.

The Nobel prizes, amounting to about $40,000 each, have been distributed by the King of Sweden with the usual ceremonies. The prize-winners in science—Professors Van der Waals (physics), Wallach (chemistry) and Kossel (medicine)—were present to receive their prizes and give the statutory lectures.

THE

POPULAR SCIENCE

MONTHLY.

MARCH, 1911

EHRLICH'S SPECIFIC THERAPEUTICS IN RELATION TO SCIENTIFIC METHOD

By FIELDING H. GARRISON, M.D.

ARMY MEDICAL MUSEUM, WASHINGTON, D. C.

AN almost negligible mortality ratio of 12 deaths in 12,000 cases of syphilis treated by "606" is the record which Professor Ehrlich was able to produce at the Königsberg meeting of German scientists,[1] and in these fatalities, accidental circumstances like shock, heart-failure and extreme debility were coefficients of greater moment than the acid and toxic nature of the remedy itself. As compared with the high ratio of successful treatment—probably towards 90 per cent. or more—the result is significant and striking. As the administration of "606" by injection is exceedingly painful in the first stages, Ehrlich compares it with operative surgery in that it can never be given without a certain risk in desperate cases, yet is better worth trying than to leave the patient to suffer or die. Its use is interdicted in disease of the heart, blood vessels or kidneys or in advanced stages of nervous disease, and, with characteristic reserve and caution, its author declines to make any premature claims regarding the cure of the disease with a single dose, although this is the avowed and ultimate of his *therapia sterilisans*

[1] As reported in *Die Heilkunde*, Berlin, October, 1910, 357. For a fuller account, see the transactions of the Deutsche Naturforscher und Aerzte as reported in the *Deutsche medizinische Wochenschrift* (reprinted by G. Thieme, Leipzig, 1910). Subsequent statistics show that the mortality ratio remains about one in 1,000 cases (.01 per cent.). It may be said that expression "606" is not a trade name, but a convenient abbreviation for the successful term and end of a series of 606 new compounds made and tested. Chemically "606" is the hydrochlorate of dioxydiamido-arsenobenzol, and was first tried out by Ehrlich's Japanese assistant, Dr. S. Hata. On account of its extreme acidity, it is now neutralized with caustic soda and administered as the sodium salt, the empirical formula of which might be written $C_{12}H_{10}O_2N_2Na_2As_2$. It has recently been patented as "salvarsan."

magna. Before any conclusions can be formulated, the after-effects of the remedy must be studied, he says, for some months running, possibly a year or more. Will "606" permanently abort or check an attack of syphilis, or will it, like a drastic silver nitrate treatment in gonorrhœa, cause some of the pathogenic organisms to burrow into the deep tissues, only to crop out as an embarrassing recrudescence later on? Will it have any effect upon the posterity of syphilitics or upon those strange parasyphilitic affections, locomotor ataxia and general paralysis? Will it produce a generation of paretics and ataxics as some think mercury does? These and similar questions that suggest themselves can only be resolved by a study of the treated cases over long periods of time. The fact that suckling infants are cured after their mothers have received the injection would argue, Ehrlich thinks, that something like antibodies are formed in the maternal milk, indicating that "606" acts like a true antitoxin. This would seem to be borne out by the disappearance of the Wassermann serodiagnostic reaction shortly after the injection is given. I am informed by Captain Charles F. Craig, of the Army Medical Department, that in 33 United States soldiers recently treated with "606" (medium doses of 0.6 gram), the syphilitic lesions and the Wassermann reaction disappeared in 28 cases during periods of time ranging from five days to about two months, the men being returned to duty as cured.[2] Statistical results like these are now mounting up by the hundreds in the medical journals of the world, and if the effects of the drug are permanent it is probable that syphilis will become, in due course, a rare disease in civilized communities. There are some who have still enough of "*odium theologicum*" in their composition to think this disease a sort of divine punishment for the social evil, and that its suppression would imply an inevitable increase in immorality. But morality and immorality are too much the resultant of a conflict between innate disposition and social or ethical forces to be appreciably influenced by discoveries in therapeutics. These bigoted souls may take comfort in the fact that "606" is a simple chemical remedy, acting like quinine in malarial fever. It protects the innocent—the wives and children of the infected man—but, if it spares the sinner for the present, it holds out no alluring prospects for vicious indulgence in the future. "606" does not confer immunity from subsequent infection.

The scientific career of the remarkable man to whom medicine owes so much and who himself owes so little to university training is a striking example of the self-reliance and autodidactic tendencies that

[2] In the circular of instructions for the administration of "606" issued by the Surgeon General of the U. S. Army (December 13, 1910), it is directed that for present routine work among soldiers the medium dose of 0.4–0.6 gm. should be given. This may probably be increased to 1 gm. later on, when the after-effects of the remedy are ascertained.

sometimes accompany ability of the highest order. As a student, Ehrlich bore out President Eliot's theory that any young man who has real capacity usually has a better inkling of its extent, if not of its limitations, than his elders can teach him. Age and experience may perhaps indicate what youth can't do, but they have no power of predicting what it can do. It is related that when Robert Koch was once visiting the Breslau laboratories, a young student working at a table covered with staining materials was pointed out to him, with the remark: "There is our little Ehrlich. He is a first-rate stainer of tissues, but he will never pass his examinations."[3] The prediction was true. Ehrlich got his degree by courtesy, on the strength of his well-known discoveries in the histology of the blood; but doubtless his academic sponsors serenely followed the example of Kant, who, in lecturing, addressed himself to students of mean average intellect only, on the assumption that the blockheads were beyond human help, while the geniuses could take care of themselves. The young Ehrlich easily made himself recognized as a true-born scientific genius, but his example will scarcely save less careful or more luckless students from being plucked at their final examinations.

Although for practical use, Ehrlich's researches in synthetic chemistry rank near to those of Emil Fischer, he is a true Asclepiad, and his principal aim has always been to improve the diagnosis and treatment of disease. Nearly all his results are of fundamental importance for actual medicine and they are a long list. We can imagine some awarder of a Copley medal or Nobel prize recounting them: First, the improved methods of drying and fixing blood smears by heat and the staining methods which have become such a feature in recent diagnosis, notably the tri-acid stain, the fuchsine stain for tubercle bacilli and the method of intra-vital staining, the first step towards getting in touch with what is going on inside the living cell; then his discovery of five new constituents of the blood which have become basic principles in modern diagnosis; his important study of the oxygen requirements of a living organism; his diazo-test for the urine in typhoid fever; his demonstration that animals can be quantitatively immunized against the effects of vegetable poisons like abrin and ricin, as well as against the toxins of vegetable parasites; and conversely, that animal parasites have the power of immunizing themselves and their descendants against the action of drugs; his improvement of Behring's diphtheria antitoxin and his establishment of an international standard of purity for the same; his side chain theory of immunity, which led at once to such brilliant results as the Wassermann method of serodiagnosis and (in medical jurisprudence) to the precipitin tests for blood-stains (Bordet-Uhlenhuth) and the cobra-venom test for insanity (Much-Holtzmann);

[3] The anecdote is given by the late Dr. Christian A. Herter in *Jour. Am. Med. Assoc.*, Chicago, 1910, LIV., 428.

his studies in isolysins which inaugurate a physiology peculiar to the individual as opposed to the normal physiology of the species; his idea of a canonical study of the blood-serum in health and disease, so that a norm or "blood-canon" for the investigation of new or unknown conditions may be available; his demonstration that cancer may be changed into sarcoma by successive inoculations; that the growth of cancer in an animal body depends upon the presence of certain food-stuffs in that body; finally the gigantic labors involved in building up hundreds of new compounds and testing them as remedies for the two great groups of parasitic diseases, the spirilloses and the trypanosomioses, his prospective success being one of the greatest triumphs of the method of "trial and error" on record. Surely a career in scientific medicine only matched in recent times by those of Pasteur, Helmholtz, Koch and Lister.

To the orthodox chemist, who works by rule and formula, Ehrlich's experimental methods might seem mere haphazard "test-tubing," and he himself has jestingly referred to his laboratory procedure as "*Spielchemie*," an epithet which well describes the experimentation that results from the free play of a singularly acute mind. Some of his admirers have even gone so far as to say that he declines to work quantitatively. Although his own statement (in the Harben lectures) is just to the opposite effect—and all experiment that seeks the general law behind related facts is obviously quantitative in its intention—it is quite true that Ehrlich has steadfastly declined to follow Arrhenius in applying the quantitative methods of physical chemistry to the unknown entities of immunity reactions. "I have always emphasized the chemical nature of the reaction," he says, only "the formulas devised by Arrhenius and Madsen for the reactions of toxins and antitoxins explain absolutely nothing. Even in particularly favorable cases they can merely represent experimental results in the form of interpolation formulas."[4] In Ehrlich's view, the mistake made by the distinguished Swedish physicist lies in the assumption that toxins and antitoxins can be treated mathematically as simple indivisible substances, whereas there is unimpeachable evidence of their dual and multiple nature—that they can be split up into labile components of such extreme complexity as to have, so far, defied ultimate analysis. Under these conditions assumed constants become inevitably dependent variables and the physical chemist is dealing with the shifting evanescent aspects of substance in the labile state. The careful quantitative work of such a competent experimenter as Dr. W. H. Manwaring[5] has shown that, with the knowledge at present available, physico-chemical measure-

[4] Ehrlich, "Collected Studies in Immunity," New York, 1906, 578.

[5] Manwaring, *Jour. Infect. Dis.*, Chicago, 1907, IV., 219–222; *Jour. Biol. Chem.*, New York, 1907–8, III., 387–389; *Brit. Med. Jour.*, London, 1906, II., 1542–1547.

ment of the constantly variable constants of immunity reactions is like computing the dynamics of *ignes fatui*. Even if the ultimate formulæ of toxins or protoplasm could be ascertained in the laboratory, as in the case of hemoglobin or urea, it would tell chemists nothing about what they are in the living body. The ultimate phenomena of life and death are still (in Spinoza's classic phrase) of a kind "*quæ nullo numero explicari possunt*," and Ehrlich's theory, as he predicted in his Baltimore lectures, has been deeply enough rooted in experimental fact to "withstand the Northern storms." In a most interesting paper in The Popular Science Monthly,[6] Dr. A. F. A. King, of Washington, has thrown into relief the all-important point that the essential feature of a living organism is the limiting, peripheral, semiporous membrane, skin or sheath which, like the semipermeable membrane in physics, invests and insulates it, preventing it from dissipating its energy, except sparingly and under definite conditions. Detached from the investing semipermeable membrane, Dr. King holds that cellular protoplasm is "neither alive nor dead but between the two." The telling feature in Ehrlich's attack upon disease is the unique way in which he has visualized and dealt with those basic border-line substances which, *in vitro*, if not *in vivo*, are "neither alive nor dead, but between the two." He has clearly seen that the mathematical expressions for such labile complexes as protoplasm or toxins do not come under Sir William Hamilton's category of "real numbers." They may be vectorial quantities or relations like those of electrical science, and might be represented specially, graphically, vectorially or stereochemically to the mind's eye as Ehrlich has succeeded in doing; or they might be vaguely formulated as qualitative relations by the differential calculus. Quantities in the fixed arithmetical sense they are surely not. Ehrlich's method might be called a qualitative way of approaching apparently quantitative problems of extreme complexity, a sort of rough calculus of variations carried out in the laboratory under conditions in which the variables are well-nigh legion. His success has been due to his unrivaled knowledge of the intravital and distributive relations of different drugs, particularly of dye-stuffs and, on the theoretical side, to what he calls his "chemicoplastic imagination." Such a feat of fantasy as his side-chain theory is not only solidly built up on experimental fact, but is intimately concerned with the architectonics of stereochemical formulæ and with certain space-intuitions which are coming to be pretty generally accepted by organic chemists to-day. So we find Professor H. E. Armstrong, of London, stating at the Winnipeg meeting of the British Association (1910)[7] that for the modern chemist "the tetrahedron is the symbol of the functional activities of carbon," that "even the paraffins are not to be visualized as so many ducks strung upon a ram-

[6] The Popular Science Monthly, September, 1909, 289–296.

[7] Rep. Brit. Ass. Adv. Sc., 1909, London, 1910, 438, 446.

rod Munchhausen fashion, but as forming curls, according to the natural set of affinities"; and that "protoplasm, in fact, may be pictured as made up of a large number of curls, like a judge's wig—all in intercommunication through some center, connected here and there, perhaps, by lateral bonds of union." Ehrlich's conception of the molecule of functionally active protoplasm as consisting of a fundamental nucleus plus a large number of different chemical receptors or side chains is obviously at one with this stereochemical picture and he began to apply it as far back as 1885, in his studies on the oxygen requirements of the organism.[8] In this important work he makes it clear that what he terms "color-analytics" (*farbenanalytische Studien*) is the most accessible way of investigating the intimate mechanism of intracellular or protoplasmic chemistry. He was early impressed (or as he himself puts it "obsessed") with the idea of a selective and distributive relation between definite chemical substances and definite body-tissues of the kind which chemists are agreed to describe as special "affinity."[9] Starting with Hoppe-Seyler's observation that the emission and absorption of light in chlorophyll is accomplished, not by the entire chlorophyll molecule, but by certain specialized groups of atoms in it, he proceeds to outline the germinal idea of his side-chain theory, viz., that in the living cell the peripheral nutritive and excretory processes are accomplished by specialized atom groups of the protoplasmic molecule—the chemoreceptors. Suppose some extraneous substance, *e. g.*, a food, a drug, or a poison, to be brought in juxtaposition with these peripheral receptive side-chains. Expressed in terms of thermodynamic chemistry we have the familiar Gibbsian problem in chemical equilibrium which Roozeboom has so picturesquely described as "the sociology of chemical substances." If the chemical and thermal relation of the substances is such that they will immediately and definitely combine, we shall have chemical and thermodynamic equilibrium; but if the effect of the external substance is stimulative or catalytic, the living protoplasm, having greater chemical energy and higher chemical potentiality, will expel a certain portion of itself to combine with the latter. Expressed in terms of stereochemistry, equilibrium is accomplished by the chemical

[8] "Das Sauerstoff-Bedürfniss des Organismus: Eine farbenanalytische Studie," Berlin, p. 885.

[9] It is interesting to note that the quasi-sexual concept of "chemical affinity" was first employed in science by a physician, Hermann Boerhaave ("Elementa chemiæ," Lugd. Bat., 1732, 677). Boerhaave says that when aqua regia dissolves gold the relation of the solvent to the solute is such that "each loves, unites with and holds the other" (*amat, unit, retinet*). The expression gained currency through its employment by Geoffroy and other French chemists to displace the old Newtonian concept of "attraction." (See Whewell's "History of Scientific Ideas," London, 1858, II., 15–20.) When Wagner's "Tristan und Isolde" was first produced, the symbolism of the philtre in the opera was chaffed by the humorists of the day as an instance of "chemische Liebe."

bonds of the receptor atom groups and the corresponding bonds of the external groups being so related structurally that they dovetail, or in Emil Fischer's well-known analogy, fit each other as lock and key. The extraneous substance is thus in Ehrlich's own terminology "fixed," anchored or bound by the special chemoreceptor groups or the products they throw out. Now what we know of the dynamics of cellular pathology is summed up in Carl Weigert's generalization that the amount of repair of an injured or diseased tissue is usually in excess of what is required, provided the original injury is not too great. When a cell is attacked by a toxin or poison the receptor atom groups will, unless immediately overwhelmed, gradually acquire the power of throwing into the blood detached portions or products of themselves—the antitoxins—and these new side-chains float in the neighborhood of the cell, like so many battleships to protect it from injury. Ehrlich compares these antibodies to lightning rods which draw away the destructive elements to themselves. When administered as therapeutic injections he compares them to "charmed bullets which strike only those objects for whose destruction they have been produced." This is the gist of Ehrlich's theory of immunity and its central idea of a special affinity between drugs and tissues has been the center of gravity of Ehrlich's life work. The unusual terminology which he employs—the various toxophores, toxoids, toxones, amboceptors, haptines, etc.—are simply so many tags or labels affixed to designate complex protoplasmic products of unknown composition with the action of which he has become familiar through long process of experiment. The importance of these imaginative concepts, Ehrlich insists, is in their "heuristic value." How great this heuristic value is, how it has served as an inductive principle in seeking the essentials through the labyrinth of accidentals, is seen in such a triumph of synthesis as the Wassermann method for the serodiagnosis of specific infections. Concerning this discovery Wassermann says that although the side-chain theory was for years an apple of discord among bacteriologists, a thing to look upon askance, yet he could never have hit upon so special a test without Ehrlich's imaginative picture of the mechanism of disease as a guide in his experiments.[10] Protected by parallel control tests with known syphilitic and non-syphilitic bloods, this mode of diagnosis is practically infallible, even in ataxia and paresis. As an important step forward, it changed the whole aspect of those puzzling cases of immunity from syphilis which are known as Colles's law and Profeta's law. By Colles's law a syphilitic

[10] "Die Seitenkettentheorie, der jahrelange Zankapfel im bakteriologischen Lager, hat besonders dazu geführt, Ehrlich in manchem medizinischen Kreisen als 'Theoretiker' auf dem Immunitätsgebiete zu betrachten, und den 'praktischen' Wert der Seitenkettentheorie über die Achsel anzusehen. Demgegenüber kann der Schreiber dieser Zeilen nur sagen dass man ohne die Lehren Ehrlichs beispielweise niemals die Serodiagnostik der Syphilis hätte finden können," A. Wassermann, *München. med. Wchnschr.*, 1909, LVI., 247.

child may result from a syphilitic father and an apparently healthy mother, the mother's immunity being shown by the speedy infection of a healthy wet-nurse from the child's lips, while she herself nurses with impunity. Conversely, Profeta's law asserts that an apparently healthy child may sometimes be born of a syphilitic mother (and father), in which case it may be suckled by either the mother or a syphilitic wet-nurse without danger of infection. In either case examination of the blood has demonstrated the existence of the parasites as well as the permanence of the Wassermann reaction, in the mother's blood in the first instance, in the child's in the second. It became evident, from facts of this kind, that immunity from protozoan infection (animal parasites) is not the same thing as immunity from bacterial infection (vegetable parasites). In the latter case the immunity is derived from the antitoxic products of the bacteria themselves. In the case of the animal parasites, we know nothing of the chemical sources of infection and immunity. As a matter of pure speculation, perhaps the immune mother in Colles's law and the immune child in Profeta's law may, like the bacillus carriers of typhoid fever, come under Ehrlich's immunity of the first order (natural immunity), in which the sensitive receptors have either become worn out and insensitive or no longer exist as such. Theorizing aside, the practical outcome of these details was the evident impossibility of curing parasitic diseases by special antitoxins or vaccines, and the practical necessity of finding chemical specifics which would destroy the parasites as quinine does the malarial plasmodium. The next step towards a rational chemotherapy was Ehrlich's discovery that when mice infected with trypanosomes are treated with specific dyes like trypan red in doses that fall short of complete sterilization by some assignable quantity, a race of trypanosomes can be gradually bred which will prove permanently "fast," or resistant to the effects of the drug. The power of parasites to immunize themselves and their descendants against the effect of destructive poisons led Ehrlich to his next move in attempting to checkmate them—the idea of sterilizing the patient's body *uno ictu* ("mit einem Schlag") by a single dose of medicine. It was "upon this hint that he spake" in formulating his *therapia sterilisans magna* and we are now in a position to appreciate the value of his discoveries in pharmacodynamics.

In his Harben lectures before the Royal Institute of Public Health in 1907 Ehrlich stated his conviction that pharmacology, toxicology and therapeutics are "the most important branches of medicine." In other words, he believes that the chief end of the physician is to get his patients well. Self-evident as this proposition is, it has a certain paradoxical novelty when we consider the dominance of ætiological studies (pathology and bacteriology) through the last half of the nineteenth century and the apparent *débâcle* of drug therapy which attended the rise of experimental pharmacodynamics. In such natural remedies as heat, light, electricity, hydrotherapy, climate, dietetics, hypnotism and psychotherapy, out-door exercise and simple living, the physician has many strings to his bow, apart from the more special arms of treatment like operative surgery, ophthalmology, orthopædics, etc. In respect of drugs, it is perhaps no exaggeration to say that scarcely more than a double baker's dozen are strictly reliable. Even the average practitioner of to-day will admit that in regard to general treatment of disease with drugs we are almost where we were over 2,000 years ago. Among the greater Greeks, the divine Hippocrates created surgical diagnosis and taught physicians how to group symptoms and to describe different diseases; Theophrastus Eresius, the friend and pupil of Aristotle, was the founder of scientific botany; Dioscorides made the first materia medica and Galen, the father of the experimental idea, taught the Romans how to apply it. Of the two great founders of European medicine, Galen was the abler and keener therapist, but inclined to brag about his cures. Hippocrates, who told of his failures also, was the truer clinician. The complicated and elaborate polypharmacy which Galen imposed upon medicine was exaggerated into the most filthy extremes during the Byzantine period and was further enlarged by the superior chemical knowledge of the Saracens. To this day, what Osler calls "the heavy hand of the Arabian" is sensed in the enormous bulk of our pharmacopœias. After the Revival of Learning and during the Renaissance period, the chief concern of medicine was the development of anatomy and surgery, and while a few original spirits like Saliceto, Mondeville and John of Arderne were good healers, yet down through the eighteenth century, treatment was largely an affair of lengthy "gunshot prescriptions," compounded of multifarious ingredients on the hit-or-miss principle, well-deserving of Mark Twain's comment "serve with a shovel." The tendencies of this picturesque therapy, founded upon the "doctrine of signatures," have been very prettily rhymed in the *envoy* to Kipling's recent story about old Nicholas Culpeper, the most famous of the seventeenth century quacksalvers, herb-doctors and "judicial astrologers":

Excellent herbs had our fathers of old—
  Excellent herbs to ease their pain—
Alexanders and Marigold,
  Eyebright, Orris and Elecampane,
Basil, Rocket, Valerian, Rue,
  (Almost singing themselves they run),
Vervain, Dittany, Call-me-to-you—
  Cowslip, Melilot, Rose of the Sun.
Anything green that grew out of the mould
  Was an excellent herb to our fathers of old

. . . .

Wonderful little when all is said,
  Wonderful little our fathers knew,
Half their remedies cured you dead—

Most of their teaching was quite untrue—
Look at the stars when a patient is ill,
(Dirt has nothing to do with disease)—
Bleed and blister as much as you will,
Bleed and blister as much as you please.[11]

Paracelsus, who originated the treatment of syphilis with mercurials, made a brave stand for chemical therapeutics in the sixteenth century, but there could be no scientific treatment of disease without accurate knowledge of physiology, pathology and clinical diagnosis. Harvey's physical demonstration of the circulation of the blood awoke experimental physiology from the sleep of fifteen centuries, but had to wait upon the specialization of laboratory physics and chemistry for its further advancement. Modern chemistry began with Priestley's discovery of oxygen and Lavoisier's introduction of the balance. Physical diagnosis began to be a science with the inventions and discoveries of Auenbrugger (percussion), Laennec (stethoscope and mediate auscultation), Louis (statistical interpretation), Skoda (physics of chest diseases), and Wunderlich (clinical thermometry). The therapeutics of ordinary ailments became more refined but the treatment of specific infections could not be ætiological before the development of cellular pathology by Virchow, of bacteriology by Pasteur and Koch, of medical parasitology by Manson, Laveran, Ross, Reed, Stiles and Schaudinn. In the eighteenth century medicine had been an affair of theories and systems, and in each instance the treatment was dominated by the particular view of the nature of disease—Boerhaave's, Haller's, Brown's, Cullen's or Hahnemann's. Homœopathy,[12] the most dogmatic and fantastic of these, illustrates the trend of drug therapy for over a hundred years—the tendency to treat symptoms rather than to remove the cause. About the middle of the nineteenth century we come to the so-called "therapeutic nihilism" of Vienna, in which practise degenerated into simple diagnosis. This was mainly due to the influence and example of Skoda, an unrivalled diagnostician, but incidentally a whimsical, lop-sided Czech, who claimed that although we can diagnose and describe disease, "we dare not expect by any means to cure it." Great as Skoda's scientific attainments were, his influence upon therapeutics was wholly pernicious, and it became a sort of by-word in Vienna that to be auscultated by Skoda was a possible prelude to being

[11] Rudyard Kipling, "Rewards and Fairies," Doubleday, Page & Co., New York, 1910, pp. 281, 282.

[12] Although Hahnemann's "Organon" was published in 1810, he began to practise about 1799, and his theory of therapeutics, with its attempt at systematization, is fairly characteristic of the eighteenth century. Homœopathy has had some good effect upon therapeutics in lowering the scale of dosage of drugs. In the inscription upon the pedestal of Hahnemann's statue at Washington, the original dogmatic universal affirmative "Similia similibus curantur" has been softened down to the tentative implications of the subjunctive mood: "Similia similibus *curentur*."

autopsied by Rokitansky. A diagnosis confirmed by a post-mortem became a too frequently attainable ideal and the physician of the day went far towards being the "petulant scientific coxcomb" of Mr. Bernard Shaw's aversion. This sterile complacency went even further, for we read in Baas that there were deaf physicians in Vienna who could not use the stethoscope but who presumably traded upon the Skodæsque dogma that there is no treatment for disease. Meanwhile organic chemistry was forging ahead at a rate which to Helmholtz "did not seem quite rational." The science of the coal-tar products brought great numbers of new drugs into play and pharmacology became more and more exact. Experimental pharmacodynamics, however, is a plant of very recent growth, the work of such men as Schmiedeberg, Buchheim, Traube, Brunton and Cushny. After reading the text-book of Schmiedeberg's brilliant pupil Cushny[13] we get such a poor idea of the bulky pharmacopœias of recent date, that the remains of the sifting process seem very like the stock in trade of Romeo's starving apothecary—

> A beggarly account of empty boxes
> Green earthen pots, bladders and musty seeds,
> Remnants of pack thread and old cakes of roses.

"The period of constructive pharmacology," says Cushny, "has scarcely dawned: at present its chief function is destructive and critical," and he points out that remedies "generally employed may be numerated in units where they were once counted in scores." The effect of this destructive criticism upon "pharmacologic fetishisms" (as Barton calls them) is seen in the gradually changing attitude of the medical profession towards a work like Osler's "Practice," which is not only the best book on the subject in English, but also the best abused, on account of the author's very conservative feeling about drug therapeutics. As a matter of fact, Professor Osler gives with lucid, scientific precision all that can be done for a given disease; when it comes to general drugging, he says that such and such remedies may be tried: he does not guarantee that they will cure. Similarly, if we follow the teaching of one of the most eminent of recent French clinicians, the lamented Huchard, actual drug therapy may be limited to some twenty remedies or groups of remedies ("*La thérapeutique en vingt medicaments*"),[14] viz.: opium, mercury, quinine, nux vomica, digitalis, arsenic, phosphorus, ergot, belladonna, chloral, bismuth, the bromides, the hypnotics, the purgatives, the antiseptics, the anæsthetics, the antipyretics, the

[13] Cushny's "Pharmacology" (5th ed., Philadelphia, 1910) is dedicated to Schmiedeberg, "*dem Meister vom Schüler gewidmet.*" For an interesting account of recent aspects of the subject see the two papers on "Pharmacologic Fetishisms," by Dr. Wilfred M. Barton in *Jour. Am. Med. Assoc.*, Chicago, 1909, LII., 1557–1560; 1910, LV., 284–287.

[14] By Henri Huchard and Ch. Fiessinger, Paris, 1910.

nitrites, the sera and vaccines, the animal extracts. In this list it will be noted that of the few actual drugs left from the vast accumulation of centuries, nearly every one has a specific intention.

The idea of specificity in the treatment of disease had its origin in Jenner's immortal discovery of preventive inoculation, but first began to attain its full growth with the development of the bacterial theory of infection. Pasteur's preventive inoculations in anthrax and hydrophobia made a good start in the right direction, but the temporary failure of Koch's tuberculin showed that the path was a perilous and thorny one even for a man of genius. Behring's discovery of antitoxins and the success of his diphtheria antitoxin opened out new aspects of the subject, but pure serotherapy with stock antitoxins has been so far effective only in diphtheria, tetanus and serpent poisoning. The work of Sir Almroth Wright and his followers made it clear that antitoxic and antibacterial immunity are two entirely different things. In the latter case, the immunity or cure is not brought about by the dovetailing of the chemical bonds of toxins and antitoxins, but by stimulating the tissues to produce opsonic or sauce-like materials which make the pathogenic organisms more easily absorbable by the white blood corpuscles. This is the phagocytosis of Metchnikoff and is best attained by the injection of dead cultures or vaccines of the organisms producing the disease. Vaccinotherapy has been so far successful in such blood poisonings as puerperal septicæmia or furunculosis, in gonorrhœal rheumatism, and particularly in preventive inoculations against typhoid fever. In such a toxæmia as puerperal fever, the infection may be due to many different bacteria and here the treatment reaches such a high degree of specificity that it becomes, in effect, individual and autogenous, the vaccines being prepared from the blood of the lying-in woman to attain the Ehrlich ideal of "charmed bullets." In typhoid fever, the success in the case of some 14,000 United States soldiers recently vaccinated against the disease under the direction of Major F. F. Russell, has been such that Major Russell thinks the time has come when this preventive measure should be extended to the civil population also.[15] The discovery that a large number of specific infections—notably malarial fever, sleeping sickness, relapsing fever, hook-worm infection and syphilis—are due to animal parasites, revealed still another class of diseases requiring specific treatment—a class which probably includes cancer, rheumatic fever, smallpox, yellow fever, pellagra, hydrophobia and most diseases of the skin. Ehrlich was late in entering this field of specific therapeutics, but he immediately began to dominate it, for it was he who put the treatment of protozoan infection upon a scientific basis. Having discovered that animal parasites can immunize themselves against the action of

[15] *Boston Med. and Surg. Journal*, Jan. 5, 1911, 1–8.

drugs, his problem has been in each case to find a protoplasmic poison of such nature that it will not injure the patient's tissues, but will sterilize his body against the parasites in one or two injections. Success in finding such drugs must obviously depend upon an intimate knowledge of the relation between chemical structure and pharmacodynamic action and, in this obscure matter, Ehrlich has had at his fingers' ends a fund of practical information that is almost unprecedented. It is known that the physiological action of the organic radical in a drug molecule is the same, no matter what combination it enters into, while the inert parts of the molecule may alter the degree, but not the kind of action. Thus the anesthetic effect of cocaine or its derivatives is due to the amido-benzoic acid group in the cocaine molecule. Again the most toxic compounds are those which most rapidly liberate the active atom group in the molecule by decomposition, as in the case of many coal-tar products. Building upon facts of this kind, Ehrlich has in a surprisingly short time turned out definite effective remedies like methylene blue for quartan fever, trypan red in bovine piroplasmosis (Texas fever), arsenophenylglycine for the trypanosomiases (sleeping sickness in man, surra and mal de caderas in horses), dioxydiamidoarsenobenzol or "606" for the spirilloses (syphilis and relapsing fever). The technical and structural details of this wonderful piece of chemical research have been very thoroughly and ably described in a recent number of *Science* by Dr. H. Schweitzer[16] to which our readers may be referred. One instance of the extreme specialization of Ehrlich's chemotherapeutic knowledge may be quoted, his theorem that effective remedies for sleeping sickness must be "tetrazo colors derived from naphthalen disulpho-acids with the sulpho-groups in the 3.6 position."[17] The labors involved in building up and trying out several hundred of these new compounds was enormous, and in order to facilitate a system of exclusion, Ehrlich utilized his discovery of parasitic immunity against drugs in his device of a "*cribrum therapeuticum*" or therapeutic sieve, which will immediately classify any new chemotherapeutic substance in regard to its destructive effects upon pathogenic parasites. This is accomplished by rendering different parasites resistant to various drugs (*e. g.,* fuchsine or atoxyl) through many generations, until finally a "strain" or breed is produced that is definitely fuchsine-fast, atoxyl-fast, etc. When a new drug is tried upon these different resistant strains, its pharmacodynamic status can be ascertained at once. If it destroys all the resistant strains it clearly belongs to a new and untried group. Ehrlich has even succeeded in cultivating strains of trypanosomes each of them re-

[16] "Ehrlich's Chemotherapy—A New Science," by Dr. H. Schweitzer, *Science*, December 9, 1910, 809–823.

[17] *Ibid.*, 815.

sistant to the action of several drugs, which simplifies such work still further. In thus employing the unstable coal-tar products to destroy organisms made up of labile protoplasm, Ehrlich has opened up an entirely new field of therapeutics. As Morgagni, the first pathologist, treated of the seats and causes of disease (*De sedibus et causis morborum*), so Ehrlich has sought (he claims) to gain a fuller knowledge of the distributive and local causal relations of the finest mechanism of drugs, *de sedibus et causis pharmacorum*.[18]

In deploying this vast chemical knowledge against protozoan disease Ehrlich has been likened to a general who aims to take a fort by investing it on all sides. In the other important respect he resembles a great commander—in the possession of an imagination lively and keen enough to figure out the enemy's possible movements as the first step towards checkmating him. The true fighter always respects his adversary, and Ehrlich, who, in profile, looks so much like Thomas Carlyle, has taught physicians to have a very wholesome respect for their adversary, the disease germ. He has seen and demonstrated that the parasites of disease can protect themselves against man's attacks, that in this respect they are as wary and fertile in resource as we. In the future history of medicine he will have his high place as the most original thinker of his time in regard to the nature of infectious disease, as a leader in synthetic chemistry, and as a foremost champion in humanity's *"Kulturkampf gegen den Tod."*

[18] Ehrlich, Harben Lectures ("Experimental Researches in Specific Therapeutics"), London, 1908, 88.

THE DISCIPLINARY VALUE OF GEOGRAPHY

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Part II. The Art of Presentation

Oral and Printed Presentation.—At the close of a study, an investigator naturally wishes to make report of his results and thus to submit them to the criticism of others than himself and his immediate teachers. He has then to consider whether the report shall take the form of an oral statement before a conference of his associates, or a written essay to be printed in a scientific journal for near and distant readers. There are certain striking differences between the styles appropriate to these two forms of presentation. An oral report ought to be so clear that its meaning can be apprehended during its presentation; hence it must be neither so terse as to be obscure, nor so full of detail as to be confusing. It should be spoken, rather than read from manuscript, because the style of a written presentation is usually so condensed that it is not easily understood when read aloud. A printed report may, on the other hand, either from terseness of style or from abundance of detail, require more than one reading before its full value is learned. A printed report may, if desired, be condensed into a short paragraph of ten or twenty lines, giving only an abstract of results; or it may be expanded to fill many pages. An oral report should not be so short as to seem abrupt, or so long as to be fatiguing. An oral report can not be followed easily, if it contain many local names, or numerous quantitative statements and bibliographic citations; but such details are appropriate enough in a printed report, if the subject treated and the space allowed makes them desirable. The selection of topics and the order of presentation should be very carefully considered in an oral report, because the hearers have no escape from the speaker's plan: they must listen to the first part, first, and to the last part, last; and they must hear the whole of it. In a printed report, selection and order are still important, but for different reasons, inasmuch as the readers may run over printed pages rapidly if they wish to, skipping such details as they do not care to read, and even reading the last page first, if a summary is presented only at the end instead of also at the beginning. The preparation of an oral report demands critical care in the selection and definition of terms and in the phrasing of explanations; so that the right words may be immediately used; for the recall of a spoken word is impossible, and the correction of a wrong word by substituting another for it, is awkward and distracting. The preparation of a printed report also demands care, but the opportunity for revision is here of longer duration, extending even to the correction of the paged proof. Finally, the diagrams, pictures and maps appropriate for a printed essay may be minutely accurate; but such accuracy is generally unnecessary, if not indeed undesirable, in the illustrations that accompany a spoken report.

In view of these contrasts, it is evidently desirable that an investigator should consider the use that he proposes to make of a report while he is preparing it; just as he must consider the intellectual standing of the audience or of the readers to whom it is addressed. Practice in the preparation of reports of different grades is therefore an important part of the training of any student who wishes, in his maturer years, to do his share in guiding the thought of the part of the world that is interested in the subject which he cultivates. He should have actual experience in the delivery of both short and long oral reports, sometimes in elementary form for the easy edification of young hearers, sometimes in advanced technical form for keen criticism by older hearers; also in the writing of short and long reports of elementary and of advanced style. Conscious effort and repeated opportunity are necessary for safe and rapid progress.

Five Styles of Presentation.—Reports, whether spoken or printed, differ also in the method of presentation that they follow. The more commonly employed methods may be named the narrative, the inductive, the analytic, the systematic and the regional methods, each of which may be advantageously employed in certain cases. The narrative method is suitable in rendering preliminary account of journeys in new fields, rather than final account of elaborate investigations; the inductive method is serviceable in reporting investigations of a relatively simple character, in which abundant facts lead to an undisputed result; the analytical method serves for more elaborate investigations, in which several rival hypotheses have to be tested and a safe explanation discovered and demonstrated; the systematic, when the related results of many studies are to be compared, classed and arranged; and the regional, for the climax of geographical work, when a specified district is to be described. These various methods may of course be modified or combined to suit individual needs, and various other methods may be invented; but we can here give further attention only to the five announced, with particular reference to their use in oral reports. What has been said above as to the contrast between oral and written presentation may suffice for the present to indicate the manner in which a report that is to be printed and read must differ from one that is to be spoken and heard.

The Narrative Method.—The presentation of events, observations and reflections in a chronological order is the essential feature of the narrative method. A diary kept during the progress of an excursion, an investigation or a journey, forms the natural basis for a presentation of this kind. Such a diary should include the writer's reflections as well as his observations; it should contain due account of such subjective matters as personal adventures, with their difficulties and successes, as well as of more objective matters, such as landscapes, climate, people, books, maps and so on. A judicious selection from a diary of this kind will suffice to give a good impression of the physical and mental path followed by an explorer or investigator, and of the varied experiences encountered along it, as well as of the results attained at its end. Appropriate emphasis should be placed upon items of greater importance, so as to prevent too monotonous a recital. The hearers will be aided in understanding the speaker's work, if a clear statement of the object sought is made at the beginning, and a succinct summary of the results gained is presented at the end.

The narrative method is certainly simpler than any other, as to composition and delivery; it is therefore the one which a student may adopt to advantage, the first time he is to make an oral report in a conference. It is also particularly appropriate when entertainment rather than demonstration is intended; hence it is often employed at large popular meetings of geographical societies. In such cases, colloquial rather than technical terms, and an empirical rather than an explanatory style of description are usually employed; but a technical and explanatory style may be used in narration, without stopping for definitions and demonstrations, if the speaker prefers it and if the hearers may be fairly expected to understand it. Under such conditions a general explanatory summary, presented at the beginning without argument or proof, serves well as an introduction. Space for such a summary can often be gained by omitting apologetic introductory remarks.

The narrative method is appropriate in scientific gatherings when the successive steps of home study or the successive events of a journey are of so exceptional a nature as to be as interesting as the results to which they led. Such, however, will seldom be the case in the work of university students, to whom this supplement is addressed; they will therefore seldom have occasion to employ the narrative method after first practise in it, as above indicated: but it is certainly profitable for every student to make at least one intentional trial in narrative, in order to learn something of its quality and value from his own experience in preparing and presenting it, and from the behavior of his audience in listening to it and commenting upon it. If it costs a speaker some regrets to omit certain items of personal experience, in order to compress his report into the time allotted for it, he may be comforted on realizing that his hearers will not share his regrets, because they will be unaware that anything of interest has been omitted. If, however, his narrative arouses animated questioning at its end, he may then very effectively introduce items that were before held in reserve. In every case, inasmuch as complete narration is impossible, it is desirable to select for it such items as form a reasonably connected story, dominated by a single line of interest; for in this way the attention of the hearers will be much better held than by a rambling recital of disconnected items. Even in so unambitious a method of presentation as the narrative, it is well to recognize that artistic form and graceful phrasing deserve careful attention. These matters should not be so much neglected as to give ground for the reproach, often directed against the work of scientists, that their style is awkward, involved and obscure, or that their interest in substance causes them to neglect form. It well repays a speaker's care in these subordinate matters, if his audience, often more by their manner than by their words, show that they have had pleasure as well as profit in listening to him. Similarly, such trifles as clear enunciation and easy gestures should be cultivated from the first, just as the ridiculous habit of talking to the blackboard or of . . . eh . . . eh . . . awkwardly pausing . . . eh . . . eh . . . when there is nothing . . . eh . . . eh . . . to pause for, should be avoided

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Most of their teaching was quite untrue—
Look at the stars when a patient is ill,
(Dirt has nothing to do with disease)—
Bleed and blister as much as you will,
Bleed and blister as much as you please.[11]

Paracelsus, who originated the treatment of syphilis with mercurials, made a brave stand for chemical therapeutics in the sixteenth century, but there could be no scientific treatment of disease without accurate knowledge of physiology, pathology and clinical diagnosis. Harvey's physical demonstration of the circulation of the blood awoke experimental physiology from the sleep of fifteen centuries, but had to wait upon the specialization of laboratory physics and chemistry for its further advancement. Modern chemistry began with Priestley's discovery of oxygen and Lavoisier's introduction of the balance. Physical diagnosis began to be a science with the inventions and discoveries of Auenbrugger (percussion), Laennec (stethoscope and mediate auscultation), Louis (statistical interpretation), Skoda (physics of chest diseases), and Wunderlich (clinical thermometry). The therapeutics of ordinary ailments became more refined but the treatment of specific infections could not be ætiological before the development of cellular pathology by Virchow, of bacteriology by Pasteur and Koch, of medical parasitology by Manson, Laveran, Ross, Reed, Stiles and Schaudinn. In the eighteenth century medicine had been an affair of theories and systems, and in each instance the treatment was dominated by the particular view of the nature of disease—Boerhaave's, Haller's, Brown's, Cullen's or Hahnemann's. Homœopathy,[12] the most dogmatic and fantastic of these, illustrates the trend of drug therapy for over a hundred years—the tendency to treat symptoms rather than to remove the cause. About the middle of the nineteenth century we come to the so-called "therapeutic nihilism" of Vienna, in which practise degenerated into simple diagnosis. This was mainly due to the influence and example of Skoda, an unrivalled diagnostician, but incidentally a whimsical, lop-sided Czech, who claimed that although we can diagnose and describe disease, "we dare not expect by any means to cure it." Great as Skoda's scientific attainments were, his influence upon therapeutics was wholly pernicious, and it became a sort of by-word in Vienna that to be auscultated by Skoda was a possible prelude to being

[11] Rudyard Kipling, "Rewards and Fairies," Doubleday, Page & Co., New York, 1910, pp. 281, 282.

[12] Although Hahnemann's "Organon" was published in 1810, he began to practise about 1799, and his theory of therapeutics, with its attempt at systematization, is fairly characteristic of the eighteenth century. Homœopathy has had some good effect upon therapeutics in lowering the scale of dosage of drugs. In the inscription upon the pedestal of Hahnemann's statue at Washington, the original dogmatic universal affirmative "Similia similibus curantur" has been softened down to the tentative implications of the subjunctive mood: "Similia similibus *curentur*."

autopsied by Rokitansky. A diagnosis confirmed by a post-mortem became a too frequently attainable ideal and the physician of the day went far towards being the "petulant scientific coxcomb" of Mr. Bernard Shaw's aversion. This sterile complacency went even further, for we read in Baas that there were deaf physicians in Vienna who could not use the stethoscope but who presumably traded upon the Skodæsque dogma that there is no treatment for disease. Meanwhile organic chemistry was forging ahead at a rate which to Helmholtz "did not seem quite rational." The science of the coal-tar products brought great numbers of new drugs into play and pharmacology became more and more exact. Experimental pharmacodynamics, however, is a plant of very recent growth, the work of such men as Schmiedeberg, Buchheim, Traube, Brunton and Cushny. After reading the text-book of Schmiedeberg's brilliant pupil Cushny[13] we get such a poor idea of the bulky pharmacopœias of recent date, that the remains of the sifting process seem very like the stock in trade of Romeo's starving apothecary—

> A beggarly account of empty boxes
> Green earthen pots, bladders and musty seeds,
> Remnants of pack thread and old cakes of roses.

"The period of constructive pharmacology," says Cushny, "has scarcely dawned: at present its chief function is destructive and critical," and he points out that remedies "generally employed may be numerated in units where they were once counted in scores." The effect of this destructive criticism upon "pharmacologic fetishisms" (as Barton calls them) is seen in the gradually changing attitude of the medical profession towards a work like Osler's "Practice," which is not only the best book on the subject in English, but also the best abused, on account of the author's very conservative feeling about drug therapeutics. As a matter of fact, Professor Osler gives with lucid, scientific precision all that can be done for a given disease; when it comes to general drugging, he says that such and such remedies may be tried: he does not guarantee that they will cure. Similarly, if we follow the teaching of one of the most eminent of recent French clinicians, the lamented Huchard, actual drug therapy may be limited to some twenty remedies or groups of remedies ("*La thérapeutique en vingt medicaments*"),[14] viz.: opium, mercury, quinine, nux vomica, digitalis, arsenic, phosphorus, ergot, belladonna, chloral, bismuth, the bromides, the hypnotics, the purgatives, the antiseptics, the anæsthetics, the antipyretics, the

[13] Cushny's "Pharmacology" (5th ed., Philadelphia, 1910) is dedicated to Schmiedeberg, "*dem Meister vom Schüler gewidmet.*" For an interesting account of recent aspects of the subject see the two papers on "Pharmacologic Fetishisms," by Dr. Wilfred M. Barton in *Jour. Am. Med. Assoc.*, Chicago, 1909, LII., 1557–1560; 1910, LV., 284–287.

[14] By Henri Huchard and Ch. Fiessinger, Paris, 1910.

nitrites, the sera and vaccines, the animal extracts. In this list it will be noted that of the few actual drugs left from the vast accumulation of centuries, nearly every one has a specific intention.

The idea of specificity in the treatment of disease had its origin in Jenner's immortal discovery of preventive inoculation, but first began to attain its full growth with the development of the bacterial theory of infection. Pasteur's preventive inoculations in anthrax and hydrophobia made a good start in the right direction, but the temporary failure of Koch's tuberculin showed that the path was a perilous and thorny one even for a man of genius. Behring's discovery of antitoxins and the success of his diphtheria antitoxin opened out new aspects of the subject, but pure serotherapy with stock antitoxins has been so far effective only in diphtheria, tetanus and serpent poisoning. The work of Sir Almroth Wright and his followers made it clear that antitoxic and antibacterial immunity are two entirely different things. In the latter case, the immunity or cure is not brought about by the dovetailing of the chemical bonds of toxins and antitoxins, but by stimulating the tissues to produce opsonic or sauce-like materials which make the pathogenic organisms more easily absorbable by the white blood corpuscles. This is the phagocytosis of Metchnikoff and is best attained by the injection of dead cultures or vaccines of the organisms producing the disease. Vaccinotherapy has been so far successful in such blood poisonings as puerperal septicæmia or furunculosis, in gonorrhœal rheumatism, and particularly in preventive inoculations against typhoid fever. In such a toxæmia as puerperal fever, the infection may be due to many different bacteria and here the treatment reaches such a high degree of specificity that it becomes, in effect, individual and autogenous, the vaccines being prepared from the blood of the lying-in woman to attain the Ehrlich ideal of "charmed bullets." In typhoid fever, the success in the case of some 14,000 United States soldiers recently vaccinated against the disease under the direction of Major F. F. Russell, has been such that Major Russell thinks the time has come when this preventive measure should be extended to the civil population also.[15] The discovery that a large number of specific infections—notably malarial fever, sleeping sickness, relapsing fever, hook-worm infection and syphilis—are due to animal parasites, revealed still another class of diseases requiring specific treatment—a class which probably includes cancer, rheumatic fever, smallpox, yellow fever, pellagra, hydrophobia and most diseases of the skin. Ehrlich was late in entering this field of specific therapeutics, but he immediately began to dominate it, for it was he who put the treatment of protozoan infection upon a scientific basis. Having discovered that animal parasites can immunize themselves against the action of

[15] *Boston Med. and Surg. Journal*, Jan. 5, 1911, 1–8.

drugs, his problem has been in each case to find a protoplasmic poison of such nature that it will not injure the patient's tissues, but will sterilize his body against the parasites in one or two injections. Success in finding such drugs must obviously depend upon an intimate knowledge of the relation between chemical structure and pharmacodynamic action and, in this obscure matter, Ehrlich has had at his fingers' ends a fund of practical information that is almost unprecedented. It is known that the physiological action of the organic radical in a drug molecule is the same, no matter what combination it enters into, while the inert parts of the molecule may alter the degree, but not the kind of action. Thus the anesthetic effect of cocaine or its derivatives is due to the amido-benzoic acid group in the cocaine molecule. Again the most toxic compounds are those which most rapidly liberate the active atom group in the molecule by decomposition, as in the case of many coal-tar products. Building upon facts of this kind, Ehrlich has in a surprisingly short time turned out definite effective remedies like methylene blue for quartan fever, trypan red in bovine piroplasmosis (Texas fever), arsenophenylglycine for the trypanosomiases (sleeping sickness in man, surra and mal de caderas in horses), dioxydiamidoarsenobenzol or "606" for the spirilloses (syphilis and relapsing fever). The technical and structural details of this wonderful piece of chemical research have been very thoroughly and ably described in a recent number of *Science* by Dr. H. Schweitzer[16] to which our readers may be referred. One instance of the extreme specialization of Ehrlich's chemotherapeutic knowledge may be quoted, his theorem that effective remedies for sleeping sickness must be "tetrazo colors derived from naphthalen disulpho-acids with the sulpho-groups in the 3.6 position."[17] The labors involved in building up and trying out several hundred of these new compounds was enormous, and in order to facilitate a system of exclusion, Ehrlich utilized his discovery of parasitic immunity against drugs in his device of a "*cribrum therapeuticum*" or therapeutic sieve, which will immediately classify any new chemotherapeutic substance in regard to its destructive effects upon pathogenic parasites. This is accomplished by rendering different parasites resistant to various drugs (*e. g.*, fuchsine or atoxyl) through many generations, until finally a "strain" or breed is produced that is definitely fuchsine-fast, atoxyl-fast, etc. When a new drug is tried upon these different resistant strains, its pharmacodynamic status can be ascertained at once. If it destroys all the resistant strains it clearly belongs to a new and untried group. Ehrlich has even succeeded in cultivating strains of trypanosomes each of them re-

[16] "Ehrlich's Chemotherapy—A New Science," by Dr. H. Schweitzer, *Science*, December 9, 1910, 809–823.

[17] *Ibid.*, 815.

sistant to the action of several drugs, which simplifies such work still further. In thus employing the unstable coal-tar products to destroy organisms made up of labile protoplasm, Ehrlich has opened up an entirely new field of therapeutics. As Morgagni, the first pathologist, treated of the seats and causes of disease (*De sedibus et causis morborum*), so Ehrlich has sought (he claims) to gain a fuller knowledge of the distributive and local causal relations of the finest mechanism of drugs, *de sedibus et causis pharmacorum.*[18]

In deploying this vast chemical knowledge against protozoan disease Ehrlich has been likened to a general who aims to take a fort by investing it on all sides. In the other important respect he resembles a great commander—in the possession of an imagination lively and keen enough to figure out the enemy's possible movements as the first step towards checkmating him. The true fighter always respects his adversary, and Ehrlich, who, in profile, looks so much like Thomas Carlyle, has taught physicians to have a very wholesome respect for their adversary, the disease germ. He has seen and demonstrated that the parasites of disease can protect themselves against man's attacks, that in this respect they are as wary and fertile in resource as we. In the future history of medicine he will have his high place as the most original thinker of his time in regard to the nature of infectious disease, as a leader in synthetic chemistry, and as a foremost champion in humanity's *"Kulturkampf gegen den Tod."*

[18] Ehrlich, Harben Lectures ("Experimental Researches in Specific Therapeutics"), London, 1908, 88.

THE DISCIPLINARY VALUE OF GEOGRAPHY

By Professor W. M. DAVIS
HARVARD UNIVERSITY

Part II. The Art of Presentation

Oral and Printed Presentation.—At the close of a study, an investigator naturally wishes to make report of his results and thus to submit them to the criticism of others than himself and his immediate teachers. He has then to consider whether the report shall take the form of an oral statement before a conference of his associates, or a written essay to be printed in a scientific journal for near and distant readers. There are certain striking differences between the styles appropriate to these two forms of presentation. An oral report ought to be so clear that its meaning can be apprehended during its presentation; hence it must be neither so terse as to be obscure, nor so full of detail as to be confusing. It should be spoken, rather than read from manuscript, because the style of a written presentation is usually so condensed that it is not easily understood when read aloud. A printed report may, on the other hand, either from terseness of style or from abundance of detail, require more than one reading before its full value is learned. A printed report may, if desired, be condensed into a short paragraph of ten or twenty lines, giving only an abstract of results; or it may be expanded to fill many pages. An oral report should not be so short as to seem abrupt, or so long as to be fatiguing. An oral report can not be followed easily, if it contain many local names, or numerous quantitative statements and bibliographic citations; but such details are appropriate enough in a printed report, if the subject treated and the space allowed makes them desirable. The selection of topics and the order of presentation should be very carefully considered in an oral report, because the hearers have no escape from the speaker's plan: they must listen to the first part, first, and to the last part, last; and they must hear the whole of it. In a printed report, selection and order are still important, but for different reasons, inasmuch as the readers may run over printed pages rapidly if they wish to, skipping such details as they do not care to read, and even reading the last page first, if a summary is presented only at the end instead of also at the beginning. The preparation of an oral report demands critical care in the selection and definition of terms and in the phrasing of explanations; so that the right words may be immediately used; for the recall of a spoken word is impossible, and the correction of a wrong word by substituting another for it, is awkward and distracting. The preparation of a printed report also demands care, but the opportunity for revision is here of longer duration, extending even to the correction of the paged proof. Finally, the diagrams, pictures and maps appropriate for a printed essay may be minutely accurate; but such accuracy is generally unnecessary, if not indeed undesirable, in the illustrations that accompany a spoken report.

In view of these contrasts, it is evidently desirable that an investigator should consider the use that he proposes to make of a report while he is preparing it; just as he must consider the intellectual standing of the audience or of the readers to whom it is addressed. Practice in the preparation of reports of different grades is therefore an important part of the training of any student who wishes, in his maturer years, to do his share in guiding the thought of the part of the world that is interested in the subject which he cultivates. He should have actual experience in the delivery of both short and long oral reports, sometimes in elementary form for the easy edification of young hearers, sometimes in advanced technical form for keen criticism by older hearers; also in the writing of short and long reports of elementary and of advanced style. Conscious effort and repeated opportunity are necessary for safe and rapid progress.

Five Styles of Presentation.—Reports, whether spoken or printed, differ also in the method of presentation that they follow. The more commonly employed methods may be named the narrative, the inductive, the analytic, the systematic and the regional methods, each of which may be advantageously employed in certain cases. The narrative method is suitable in rendering preliminary account of journeys in new fields, rather than final account of elaborate investigations; the inductive method is serviceable in reporting investigations of a relatively simple character, in which abundant facts lead to an undisputed result; the analytical method serves for more elaborate investigations, in which several rival hypotheses have to be tested and a safe explanation discovered and demonstrated; the systematic, when the related results of many studies are to be compared, classed and arranged; and the regional, for the climax of geographical work, when a specified district is to be described. These various methods may of course be modified or combined to suit individual needs, and various other methods may be invented; but we can here give further attention only to the five announced, with particular reference to their use in oral reports. What has been said above as to the contrast between oral and written presentation may suffice for the present to indicate the manner in which a report that is to be printed and read must differ from one that is to be spoken and heard.

The Narrative Method.—The presentation of events, observations and reflections in a chronological order is the essential feature of the narrative method. A diary kept during the progress of an excursion, an investigation or a journey, forms the natural basis for a presentation of this kind. Such a diary should include the writer's reflections as well as his observations; it should contain due account of such subjective matters as personal adventures, with their difficulties and successes, as well as of more objective matters, such as landscapes, climate, people, books, maps and so on. A judicious selection from a diary of this kind will suffice to give a good impression of the physical and mental path followed by an explorer or investigator, and of the varied experiences encountered along it, as well as of the results attained at its end. Appropriate emphasis should be placed upon items of greater importance, so as to prevent too monotonous a recital. The hearers will be aided in understanding the speaker's work, if a clear statement of the object sought is made at the beginning, and a succinct summary of the results gained is presented at the end.

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It will often happen that a study may cover so wide a field or that a journey may bring to light so varied an assortment of facts, that an inductive presentation of all of them would be distracting, by reason of leading along many diverse lines. It is then advisable, in view of the necessity of compressing the labor of weeks or months into an hour of speaking, as well as in view of the importance of concentrating the attention upon the moderate number of points that an audience can fairly apprehend, to allow no more than light or brief mention to many topics, if indeed most of them are not wholly omitted, and to select for inductive presentation only such part of the whole story as lends itself to orderly arrangement, culminating in as novel and as interesting a climax as possible. Clear marching order of successive items is indeed particularly desirable in inductive presentation. It is furthermore highly important that, while the speaker is marshalling his facts in systematic order, his conclusion should not become so plain that his audience perceives it before he announces it; for nothing is less effective than for a speaker finally to state as a novelty a conclusion which his hearers have reached before him. If there is any danger of so untoward a result, the speaker will do well to introduce his conclusion at some midway point, so as to be sure that his hearers shall not anticipate him in arriving at it.

An advantage sometimes claimed for inductive presentation is that it is safe; but this quality, particularly in somewhat complex problems, is more apparent than real. Presentation truly has everything to do with the clearness with which the results of an investigation may be apprehended, but it has nothing to do with the safety of the results; their safety is altogether dependent on the critical thoroughness with which the investigation that led to them was carried on. Moreover, as was shown in the first part of this discussion, it is never the case that a conclusion, in which the unseen events of the past are largely involved, can be reached by induction alone. Invention of hypotheses, deduction of consequences, and so on, all have their share in reaching such a conclusion; hence even if an inductive order is adopted in approaching the conclusion, the whole evidence for it can not be set forth in this way. A full demonstration of such a conclusion must necessarily involve some other processes than pure induction. If the presentation appears to be purely inductive, the hearers will have a right to infer that certain important steps have been tacitly passed over; and the speaker may feel sure that if such omissions are detected by any of his hearers, they will form an unfavorable opinion, because of his want of candor or of thoroughness.

The Analytical Method.—This method is characterized by the presentation, at least in outline, of the successive steps that have led the investigator from his original field of observation to the invention of various hypotheses, to the recognition of the most successful hypothesis, and if possible to its establishment as a verified theory, following the plan set forth in the earlier part of this essay. This method is therefore most appropriate in the presentation of complicated problems which demand much theoretical supplement to observation, in the exposition of problems regarding which various unlike opinions have been held by different investigators, and before hearers who are fully able to appreciate rigorous scientific discussion. The essential feature of this method of presentation is that it should preserve the demonstrative quality of the investigation that it represents, and that it should proceed in such an order that the hearers may form a critical opinion as to the value of the conclusion reached at its end. Hence, just as in the usual presentation of a geometrical problem, so in an analytical presentation of a geographical problem, the conclusion or theorem to which the demonstration leads, is advisedly stated not only at the end, but also at the opening of the speaker's address, in order that the hearers may bear it in mind while observed facts, invented hypotheses, deduced consequences, and so on, are all set forth in proper sequence. Only when thus aided by being told the end at the beginning can hearers, who are not familiar with the problem under discussion, really form a competent and critical opinion as to the thoroughness with which it has been investigated.

In view of the short time at a speaker's disposal, the analysis of a complicated investigation can of course be presented only in abstract; but by careful selection of the chief points, it is possible not only to set forth in analytical fashion the leading facts and the most important hypotheses, but also, by impartially confronting the consequences with the facts, to exhibit with convincing clearness the grounds for the final acceptance of one hypothesis and the rejection of its competitors. It should be recognized that while a speaker is thus concerning himself largely with the discussion of past processes, he is for the time being a geologist rather than a geographer; but he can show his allegiance to his chosen science by making it clear to his hearers as well as to himself that, however much he may delve in the past, his object in doing so is solely in order better to understand the present.

In contrast with the inductive and other methods of presentation, the chief characteristic of the analytical method consists therefore in the candid completeness with which it reveals and discusses the various steps by which the investigator passes from the incomplete conception of his problem, based directly on observable facts, to the complete and comprehensive scheme which he has been led to believe is the true counterpart of the whole enchainment of facts, past and present, involved in his problem. Inductive presentation may lead, as has been shown above, to an understanding of single groups of simple facts, but it can not alone go so far as to reach the fuller meaning of combined groups of complicated facts, many of which are of past occurrence. But for that matter analytical presentation also may stop, on presenting several independent, uncorrelated explanations of separately grouped facts, and thus fail of being as broad and comprehensive as it should be. On the other hand, the desirable goal of analytical investigation and presentation is a well-correlated explanation of all the facts that have come under investigation; that is, a convincingly clear view of so much of their total history as is already past and as bears helpfully on understanding and describing their present condition. It is practically impossible to go so far as this, without adding invention, deduction, comparison, revision and final judgment to the earlier processes of observation and induction.

But there is another advantage possessed by analytical presentation, besides its comprehensiveness. It is well known that a speaker can best commend his work and himself to his hearers by a frank exposition of the reasons that have led him to certain conclusions rather than to others; and there is surely no way in which a clearer and more open exposition of the reasons for belief can be set forth than by presenting, at least in outline, the logical analytical method already described under the account of investigation.

Analytical presentation is moreover particularly to be recommended in preparation for the explanatory as contrasted with the empirical description of land forms; for inasmuch as all explanatory treatment is open to error, it is important not only to take precautions against error during investigation in every possible way, but also to make it plain to one's hearers that these precautions have actually been taken. The speaker should therefore frankly recognize the possibility of error, and then show, by critically analyzing the grounds of belief, that every precaution has been taken to insure its correctness.

During the progress of an analytical presentation, the speaker must take care to show no personal preference for one hypothesis over another; he must assume the impartial attitude of a just judge rather than the partisan attitude of a retained lawyer. He must not advocate any particular theory, or urge any special conclusion upon his hearers; it is for the facts themselves to advocate the acceptance of whatever hypothesis best accounts for them; it is for the consequences that successfully confront the facts to urge the acceptance of the hypothesis from which they were deduced. The speaker should avoid the use of such words as maintain and admit; for "maintain" implies a prejudiced persistence in an opinion and an unwillingness to revise it in the light of new facts or hypotheses; and "admit" implies the unwilling acceptance of facts or deductions which ought to be accepted willingly and hospitably, if they are at all pertinent to the problem in hand. There is indeed much significance here in the choice of words and phrases. A speaker may fairly urge upon his hearers the consideration but not the acceptance of a certain hypothesis; he may properly insist upon the importance of thorough work, but not upon the belief in his conclusions; he may hold that critical revision of all steps in theoretical work is essential to success, but he ought not to hold his theoretical results as beyond revision, however confident he may be of their correctness. His words show his state of mind in all these respects: hence the importance of selecting them carefully. If a speaker says: "Even the latest researches of other geographers have not driven me from the position which I have maintained from the first," his hearers may be excused if they regard him as not open to the consideration of new evidence.

There should never be, here or elsewhere, an appeal to the "authority" of some other investigator as a means of settling a doubtful question; the appeal should be made only to the evidence that has convinced the other investigator. If there be occasion to dissent from the opinion of other investigators, the dissent should always be expressed courteously: neither in spoken nor in printed reports should a sincere investigator allow himself to descend to disagreeable personalities, or permit himself to indulge in controversial polemics. His expressions regarding all other students of his subject, whether he agrees with them or not, should be such as shall promote personal intercourse when opportunity for it arises; for with whom can an investigator more advantageously associate than with those who pursue studies like his own, particularly if their conclusions differ from the ones that he has reached.

The analytical method of presentation, perhaps more than any other, demands of the speaker an appreciation of the dramatic element that enters, in greater or less degree, in every report made by an investigator to an audience; but the speaker's part should be that of stage manager rather than that of actor. He should stand, as it were, to one side, withdrawing his own personality so as the more effectively to bring forward the facts, hypotheses and other members of his troupe; each of which must come upon the stage at the proper time, play its part in the most effective manner, and then retire in favor of the next player. Yet while thus bringing forth the objective elements of the problem as clearly as possible, it is still entirely permissible for the speaker occasionally to speak for himself, in short interludes, as it were, and thus to interject some interesting personal story regarding the discovery of important facts; or to tell of the surprise and delight that he felt at the moment when a happy invention sprang unexpectedly into his mind; or to describe the excitement that he experienced when, on returning to the field in order to determine whether previously unnoticed facts really occurred as the deduced consequences of a certain hypothesis had led him to expect they should, he found one item after another at its appointed place and in its predicted form. But all this personal part should be played simply, without "heroics," so that the attention of the hearers shall not be too much withdrawn from the problem under discussion, or from the conclusion which it reaches.

The Systematic Method.—This method is adapted to the presentation of groups of allied facts in a classified order, according to their kind, and independent of where they occur; it is thus contrasted with regional presentation, which treats all the things that occur in a single district or region, whatever their kind. Attention is given in systematic presentation to the likenesses and differences of allied objects, these likenesses and differences being described either in an empirical or in an explanatory manner. If explanatory descriptions are adopted, the explanations on which they are based should have been previously established by induction or by analysis, and here used as already demonstrated and familiar, so that attention shall be now directed to the classification of the things that are explained, and not to the proof of their explanation: thus, however geological the analytical investigations of a student of geography may have been for a time, their truly geographical object is now set forth. Hence systematic presentation is of a grade that follows inductive and analytical presentation and precedes regional.

The kinds of things appropriate for presentation in classified order by the systematic method may be any group of forms, possessing associated similarities or related differences in structure, in process of carving, or in stage of development, and hence in form. They may be large features like plateaus and mountains or small details like river or valley meanders; but in either case they should be arranged according to the accepted principles of scientific classification, and the plan of classification should be explicitly announced. It is here important to recognize that the explanatory treatment of land forms by the aid of deduction enables one to complete the systematic classification of many forms, that would be very imperfectly treated if a purely empirical method were adopted: and it is desirable that this point should be clearly brought forth in a systematic presentation.

The general principle of classification, alluded to above, is that in first subdividing a group of phenomena, advantage should be taken of the different values of some element common to all of them. For example, all land forms are the surface expression of some kind of structure; hence structure may be well taken as the basis of a first subdivision; and its values may run from simple to complex along some appropriate order. All forms, thus classed according to structure, have been more or less affected by the action of some external process; hence each of the former structural divisions may now be again divided according to the kind of process that has acted upon it. But inasmuch as any process working upon any structure requires time for the accomplishment of effect, a third subdivision may be made according to the stage of advance reached by the external process in its work upon the structural mass; and so on, with relief and texture, or any other elements that are to be considered. It may often happen that, after one or more subdivisions have been made in this way, no single element is found which runs with different values through all the last formed groups; then each of these groups may be subdivided according to the different values of an element that it alone possesses.

Each final kind of land forms is usually represented by a typical example, which may be either an actual occurrence or an idealized instance. The more important types should be illustrated by diagrams, and all the type diagrams should be drawn according to a common plan, uniform in style and scale, so as to subordinate irrelevant dissimilarities and emphasize essential likenesses. The aid of deduction must be frequently called upon, in order to fill out a series of forms, for which only a few members are provided by observation.

Technical terms are necessarily employed rather frequently in a systematic presentation. If they are presumably new to the hearers, it is desirable first to give some account of the thing that the term names, with graphic illustration by simple diagram when possible; then the thing being clearly conceived, the technical term may be introduced as a name for it. Thus the hearers will acquire both the thing and the term in their proper relation. If the term is introduced first, the hearers are placed in the dangerous position of trying to attach a concept to a name, instead of being led to the much safer position of attaching a name to a concept.

It was pointed out in the account of narrative presentation, that a student may to advantage exercise himself in that simple method when making his first appearance before an audience. Let it now be added that he ought surely to have had practise in analytic presentation before he undertake systematic, and in systematic before he undertakes regional, for regional presentation, next to be described, is the most advanced of all methods, and its proper accomplishment demands training in all the simpler ones. Evidently, systematic studies, whether empirical or explanatory, are the essential precursors of well-planned regional studies, for it is by means of systematic studies that a student determines how competent is his treatment and how complete is his equipment; and furthermore it must be in terms already established that the features of any selected region are to be described. Let no one, therefore, undertake regional description until he has decided for himself upon the kind of description and of classification that he proposes to employ in describing the forms of his selected region, or indeed of any other region: and nothing is so helpful in making and justifying such a decision, as the experience of presenting orally a systematic scheme of classification to a sympathetic but critical audience.

The Regional Method.—Regional presentation of geographical problems may be regarded as the climax towards which all other methods advance: for regional description is the goal of geographical effort. The results of a brief excursion in the field or a rapid journey of exploration may be fittingly presented in narrative form, in which the observed facts, along with personal incidents, are told in the order in which they were noted. Results following from the study of problems which involve the selection of related forms from various fields may be presented inductively, if they are relatively simple, and analytically, if they are complex. Many kinds of things, wherever found, may be shown to have orderly relations by systematic presentation, and the classes of things thus established may be filled with graded examples by deduction, thus greatly extending the equipment of the geographer for further work. But after all this, there still remains the description of various land forms in the peculiar associations that they assume in nature, when they are found together in a given region: and the method of presenting such a description may therefore be called regional.

Regional presentation may be treated empirically, if so desired; or partly empirically, partly in terms of accidental, unintentional, traditional explanation; but for serious scientific work no method is so helpful or so accordant with the evolutionary philosophy which in the last half century has come to dominate so many fields of scientific study, as intentional, thoroughgoing, correlated, explanatory treatment. Evidently, no comprehensive treatment of this kind can be applied to best advantage in regional presentation, until the student has had practical experience with the various simpler methods of presentation already considered; hence the importance of orderly practise in various methods of presentation, as here repeatedly advised.

Both the empirical and the explanatory presentation of a regional problem should be attempted, in order to give the student a proper basis for choice between the more antiquated and the more modern method. In the purely empirical presentation, all such terms as delta and volcano must be excluded, because they have more or less suggestion of origin, instead of being, like hill and plain, limited to the naming of directly observed facts of form. In the method of thoroughgoing, conscious, correlated explanation, it is of course not intended that explanation should be insisted upon where no satisfactory explanation is found, but that search should be made for explanation everywhere, and if it is not found, explicit announcement should be made of failure to find it, and of dissatisfaction with the empirical treatment that is imposed in such cases.

A regional explanation of the explanatory kind should begin with a leading feature, not necessarily the oldest or the youngest; surely not with minor features; and a concise summary of the region should be presented at the outset, so that the hearers may learn the main theme of the report as soon as possible. For example, in the district of the middle Rhine or of south-central France, the highlands should be at once briefly presented as an uplifted peneplain of deformed structure, with residual elevations (monadnocks) surviving from the cycle in which the peneplain was worn down, and with new valleys eroded during the new cycle introduced by the uplift. At the same time a map should be used to locate the region under consideration, and a generalized diagram should serve as the graphic equivalent of the spoken summary: both the map and the diagram should so clearly serve their purpose, that a pointer—an instrument that is often overworked by inexperienced speakers—is hardly necessary. After the first brief, explanatory summary, the main facts should be stated again in more amplified form, with fuller explanatory description. Next all details may be at leisure embroidered on the general conception thus developed. If this be done skilfully, the hearers will find no difficulty in giving the proper value to each detail, or in placing it where it belongs. If the regional presentation is then extended to include the organic elements of the landscape, the forests and fields, the villages, roads and industries, may all be easily located in their proper relations to the stage on which the organic drama is played.

It is, as a rule, a mistake to begin a regional account with an inductive enumeration of separate items, which are to be gradually placed in order and given explanatory treatment. Such may have been the order of discovery; but it is not suitable for presentation. Far better is it at once, as above suggested, to plunge into the most comprehensive statement possible, so as to give immediately a generalized view of the leading features of the whole region; but it is here assumed that the audience is as advanced as the speaker, prepared like him for regional discussion by extended inductive and analytical studies, and like him well equipped with an abundance of classified type forms, so that they may easily apprehend the various kinds of forms named by the speaker in the introductory summary. If there is any doubt in this matter, it is for the speaker skilfully to devise a plan by which difficult or novel matters shall not be too soon or too rapidly presented.

Especial care should be taken regarding the use of local names in regional descriptions. It is of no avail, it is indeed confusing to an audience, if a speaker uses the name of an unknown village as a means of indicating the locality of some natural feature, such as a cliff, or a bay. The speaker may truly, by the frequent mention of the local names of distant places, show a great familiarity with that aspect of his subject, but he will at the same time show little comprehension of the small value which such names have for his hearers. Names that are generally known, such as Apennines, Nile, Titicaca, may of course be used without introduction, as guides to smaller features in their neighborhood; but it would be a mistake to say that near Brisighella the valley of the Lamone is of incised meandering form, for few hearers can be assumed to know where so unimportant a village and so small a river lie. Local features, natural or artificial, should therefore be first introduced in terms of their relation to large natural features; and only when thus properly located should their names be added. Furthermore, if allusion may be here made to a relatively trivial matter, the speaker should not indicate the location of the features that he mentions by pointing to a map and saying "*here*" or "*there*": the pointing stick says that; the speaker should say something more by giving the verbal equivalent of the pointer's indication; for example, "at the western base of the mountain range," or "on the southern shore of the lake." Similarly, such phrases as "on this side" or "in that direction" should be replaced by "on the northeastern side," and "in the same direction as that of the river flow."

May we not imagine a student, already practised in narration and induction, in analysis and classification, and now returned from a journey in classic lands, standing near a map of Italy and a diagram of his district, and saying to his hearers: Conceive a subdued range of deformed limestones in the back country, where several rivers, flowing through transverse valleys, emerge upon a lowland which they cross southwestward towards the sea; and then upon this lowland conceive a series of four large volcanoes to be built up, each some thirty or forty kilometers in diameter, but of moderate height and gentle slope, so that they form a series about 150 kilometers in length from northwest to southeast. After growth by eruption, the summits of all the cones are destroyed by engulfment, which forms calderas holding lakes in three of the cones, but in the fourth (southeasternmost) volcano the caldera is filled again by new eruptions. At the same time, consequent drainage erodes shallow radial furrows, which submaturely dissect the gentle outer slopes of the cones. The rivers from the mountainous back country are now obstructed; they turn along the depression that lies between the subdued limestone range and the long radial slopes of the volcanoes; perhaps they rise in lakes; but not until they are all confluent is an outlet found across the broad and low saddle between the third and fourth volcanoes; this being the lowest saddle presumably because these two volcanoes stand farthest apart. There the united waters of the rivers from the back country cut down a transverse consequent valley roughly a hundred meters in depth, open it to mature width, and prograde a simple cuspate delta in the sea beyond. At the sides of the main valley, the spurs between the radial consequent streams of the neighboring volcanoes are cut off by the river, and frayed out by insequent wet-weather streams into small hills of similar form and subequal height, consisting of tuff lying on the clays of the prevolcanic lowland (or sea bottom), and here, with the subdued Sabine range of the Apennines in the background (northeast) and the blue waters of the Tyrrhene sea in the foreground, on a few of these frayed out hills, not signalized otherwise from their fellows, the Eternal City was built; these hills are the Seven Hills of Rome.

Three or four minutes may be required for this introductory statement. The various specifications introduced in these few minutes—subdued mountains of deformed limestones; large volcanic cones, with calderas of engulfment replacing their original summits, and radial consequent valleys submaturely dissecting their gentle outward slopes; a consequent river, traversing the sag of a broad saddle between two neighboring volcanic slopes, eroding a mature consequent valley, and prograding a simple cuspate delta—all these specifications are easily understood by hearers who are ready to listen to explanatory regional descriptions. The relative positions of the several features may be indicated by a blackboard diagram, or by a lantern slide made from a pen and ink drawing, and are all so easily conceived that it is not really necessary to point even once to the diagram as the successive elements of the landscape are mentioned. At the end of the three minutes the hearers will have grasped the essential features of the district about Rome. Then a second and fuller statement of the same facts may be begun, from which the hearers may learn that the limestones of the Sabine mountains seem to be of subequable resistance, for the bare domes of the subdued range have rounded forms of coarse texture, without distinct exhibition of structural trends in the ridges or valleys; that there are many small irregularities in the course of the consequent valleys of the volcanic slopes, previously described as of radial arrangement, a geometrical phrase that suffices very well as a first approximation to the fact, but which thus suffices only because it serves as a good beginning for a closer approximation; that the longitudinal river in the depression between the limestone range and the volcanoes receives three branches from the back country, the northernmost and largest bearing the Tiber name to its head in the valleys of the central Apennines, the other two named the Nera and the Teverone; that the Tiber delta has been prograded about fifteen kilometers from the original river mouth at the outer side of the volcanic saddle; and so on. Thus at the end of eight or ten minutes, the hearers will be well prepared for any details that may follow; details, for example concerning various smaller calderas in the truncated volcanic cones; or concerning the meanders of the Tiber; or concerning the origin of the cascades at Tivoli by travertine aggradation at the mouth of a formerly normal and mature valley in the limestone range east of Rome. Each detail will fall easily into place, and take proper rank among its fellows.

When it is remembered that, however accurately the features of a region may be known to the geographer who has studied them on the ground, they can—apart from maps—become known to those who have not been on the ground only through such report as the observer may give concerning them, it will be recognized that the attention here directed to the art of presentation as a supplement to the science of investigation is fully deserved.

Printed Reports.—If allowance is made for the necessary contrasts between oral and printed presentation, as summarized at the beginning of this supplement, the suggestions given above as to the different styles of presentation for reports on geographical problems may apply to printed essays in scientific journals, as well as to spoken communications made at scientific meetings: but there are certain additional features of printed reports, especially if they are long and detailed, which deserve consideration. In preparing such reports, it must be borne in mind that an enormous amount of printed matter is issued in these modern times; and that even within the limits of a single science there is much more material published than can possibly be read by any one man. Hence if the author of an essay desires to increase his chance of gaining the attention of his colleagues, he ought to give particular attention to making his text easily intelligible. Several recommendable means of realizing this object may be briefly stated.

In long and detailed essays, it is extremely helpful to the reader to find a summary of contents presented in an introductory paragraph. The value of such a summary here is much the same as at the beginning of an oral report: it enables the reader, when he comes to the later pages, to perceive the bearing of each part on the whole. A summary at the end of an essay by no means takes the place of one at the beginning; for the author who places a summary only at the end of his report evidently regards that as the proper place for its reading; and hence prepares it in a style which may be easily understood at the end of the article, but which is necessarily quite unlike the style of an opening summary that is to be read as an introduction to everything that follows. Two summaries, one at the beginning in proper introductory phraseology, and one at the end in much more specialized phraseology, are valuable additions to every valuable article. But an introductory summary has still another value: it enables a reader quickly to determine whether he ought to read the rest of the essay or not, and this, in an era of over-abundant publication, is a service that will secure to the author the gratitude of many strangers to the rest of his work. Still another aid to the reader is afforded by a brief statement of the plan of treatment, may well follow the introductory summary of results; the reader can then, if he wishes, give attention only to some particular part of the essay which interests him, and pass over the rest.

Page headings and sectional headings deserve careful preparation because of their great value to the reader. Page headings are, however, often determined more by the editor of a journal or publisher of a book than by the author. But if authors more frequently protested against the undesirable form of page headings often in use, improvement in this respect might be sooner attained. It is surely of no practical value to a reader, who consults, for example, a volume of the "National Journal of Physiography," to find that name repeated at the head of every left-hand page. The name of a journal is sufficiently given on the title page and on the cover of the volume. Likewise it is not particularly helpful to read in every left-page heading of a long essay, "J. Smith," and in every right-page heading, "The Geography of Uruguay." In such an essay, the left heading should give the author's name and a short catch-title, as "Smith: Uruguay"; and the right heading should state the chief topics of the two pages that lie open with it, as "Coast and Harbors." It is always the convenience of the reader, not the preference of an editor, or the fashion of a printer, or the habit of a librarian that should determine matters of this sort. Old-fashioned habit is, however, sometimes so powerful that the reader's convenience is less thought of than consistency with a scheme of page headings adopted many years ago.

Sectional headings are usually within the control of the author. Let him then see that this authority is used for the benefit of his readers. There should be at least one sectional heading for every two or three pages; indeed a more frequent use of sectional headings is ordinarily possible and convenient. If all such headings and their page numbers are gathered in a table of contents at the beginning of a long essay, so much the better for the reader.

Good technical style is frequently neglected in making references to other authors. The titles of cited books and articles are best placed all together at the end of an article, or at the end of the chapters of a book; they should always be scrupulously accurate and complete. Citations in foot-notes, and especially such abbreviated forms as "loc. cit.," "op. cit.," "ut supra," should be avoided: indeed, foot-notes of all sorts are distracting to the reader. If they relate to the matter of the text, they can usually, by a slight change in phraseology or in arrangement, be given a better place in the body of the page. Reference to a cited author is conveniently made by small numbers inserted in the text, not in parenthesis. The citations at the end of each chapter then include, opposite the proper reference number, the author's name and initials, the full title of his book or article, and the place and date of publication if a separate book is cited; or the abbreviated title of a periodical, followed by the volume, year and first and last pages. Another approved method of citation places the year of publication and the cited page in parentheses in the text after an author's name, as "Smith ('08, 372)"—or the author's name may also be in the parenthesis, if it is not desired in the text. Then at the end of the essay or chapter, all authors are listed in alphabetical order. The advantage of this method is, that if repeated references are made to an article by the same author, the proper page for each reference is indicated in the text; and the citation is given but once, and then completely and correctly, in the alphabetical list. Reference to an author without complete citation is awkward and unsatisfying. While considering matters of technique, protest must be entered against the utterly reprehensible method of repaging reprints. The original paging should always be retained; the pages should not even be reset, in case an article begins on a left-hand page or in the lower part of a page. Reprints should furthermore always give full statement of the periodical from which they are taken, and of the volume and year of original publication. Neglect of these rules is too frequently the cause either of incorrect citations, or of a large amount of unnecessary trouble when an author has to go to the original volume in a library instead of making reference from a reprint on his own shelves.

More important, however, than these subordinate matters of technique, is the proper illustration of an article. Maps, diagrams and pictures should be used more frequently in geographical articles than is now commonly the case, particularly as in these modern days a process-cut from a pen drawing is about as cheap as the same space of text. The excuse offered by an author for the absence of appropriate drawings is too often that he cannot draw. This may suffice for authors whose education was gained at an earlier time, when geographical instruction was less developed than it is now; but for the future, such an excuse must be taken as indicating poor training. On the other hand, reproductions of poor or uninstructive photographs are becoming nowadays rather too common. A good photograph of a characteristic scene from a well-selected point of view, is admirable, but the space given to a poor photograph can often be occupied to advantage by a generalized diagram. Narrative reports should be accompanied by an easily legible route-map, and by views—either photographs or sketches—of the more significant features encountered on the narrated journey. Inductive essays should be illustrated by appropriate figures of the most significant features upon which its generalizations are based; and also by schematic diagrams in which the essential elements of a generalized conclusion are summarized. Analytical and systematic essays should include diagrams of ideal forms, as well as pictures of corresponding actual forms. Grouped block diagrams showing successive stages of development are serviceable, because they so compactly present the normal succession of a series of complicated forms, and thereby so greatly aid the understanding of the text. It may, indeed, be fairly claimed for such diagrams that, by permitting the abbreviation of explanations, they save at least as much space as they occupy. It should be added, however, that there is good reason for thinking that the full value of graphic illustrations has not yet been reached; and that active invention as well as better training will surely lead to notable advances. Regional essays should be illustrated by maps and pictures, and especially by simplified and generalized diagrams, in which the distribution of the larger features may be so clearly shown. Outline map-diagrams and profiles are so much less serviceable than block diagrams, that the latter are to be preferred whenever it is possible to prepare them.

The guiding principle here, as in the preceding suggestions, is that everything possible should be done to make the author's meaning easily and clearly intelligible to the reader.

THE WORK OF THE "ALBATROSS" IN THE PHILIPPINES

By ALBERT L. BARROWS

NORDHOFF, CAL.

THE *Albatross* is an iron, twin-screw steamer of a thousand tons displacement, built for the United States Commission of Fish and Fisheries in 1883 to enlarge upon the work of fishery investigation and deep-sea exploration begun on a small scale by the *Fishhawk,* a wooden steamer of some two hundred tons burden. Since the spring of 1888, the *Albatross* has been in Pacific waters, where she has made trips to Hawaii and Japan and through several groups of the Polynesian Islands, in addition to many seasons spent among the salmon fisheries of Alaska. For the past two years and a half this ship has been in the Philippines, making as complete a collection as possible of Philippine fish. The normal complement of the *Albatross* is about seventy-five officers and men, detailed from the United States Navy, but during her stay in the Philippines a large portion of the crew was temporarily replaced by Filipino recruits; the uniform of the American sailor is highly attractive to many a Filipino youth. The collecting operations on this cruise have been in charge of a resident naturalist with two assistants, beside two Filipino helpers in the laboratory routine and seamen detailed to the fishing boats. The National Museum has also placed representatives on board, and two Japanese artists have been employed for a part of the trip. In addition to the work of the ship, a special agent of the Bureau of Fisheries has been detailed on shore to compile data on the present supply of fishery products and the demand for them in the Philippines.

The work-room, through which all the specimens are passed, is situated amidships on the main deck. Drawing tables for the artists are hinged to the walls under the ports, and the ship's scientific library is contained in cases along the fore and after bulkheads. A small aquarium of slate and glass is fastened above the sink, and at the side of this there is a battery of four hatching jars. On the deck below this main laboratory is the storeroom, from which open the photographic dark-room and the sick-bay. The smaller specimens, after being sorted, labeled and packed into jars and bottles, are stowed away in lockers here and the larger fish are kept in copper tanks of alcohol. Most of the supplies and collecting gear are stowed in the laboratory hold below this storeroom.

The oceanic work of the *Albatross* is based upon the soundings taken with the Lucas sounding machine and sounding cups. The machine itself consists of a compact, triple-cylinder, compensating steam engine which turns a reel on which five or six thousand fathoms of steel wire are wound. Geared to the sheave over which the sounding wire runs is a register, which indicates the number of fathoms of wire reeled out.

THE "ALBATROSS" IN PORT. (Photograph by DeLong.)

For depths up to a thousand fathoms, a thirty-five pound shot is used to carry the wire down, and for greater depths a shot of sixty pounds. The shot are perforated with a two-inch hole so that they may be slipped over the cylindrical brass sounding cup. This trips automatically on striking the bottom, dropping the shot, while the sounding cup itself sinks into the mud and brings up an ounce or two as a sample, with the shells and hard remains of countless tiny animals which have played so great a part in the formation of many of the present land masses of the earth. The four or five thousand separate soundings, made by the *Albatross* during the past twenty-seven years, indicate a long and persistent bombardment of the ocean depths.

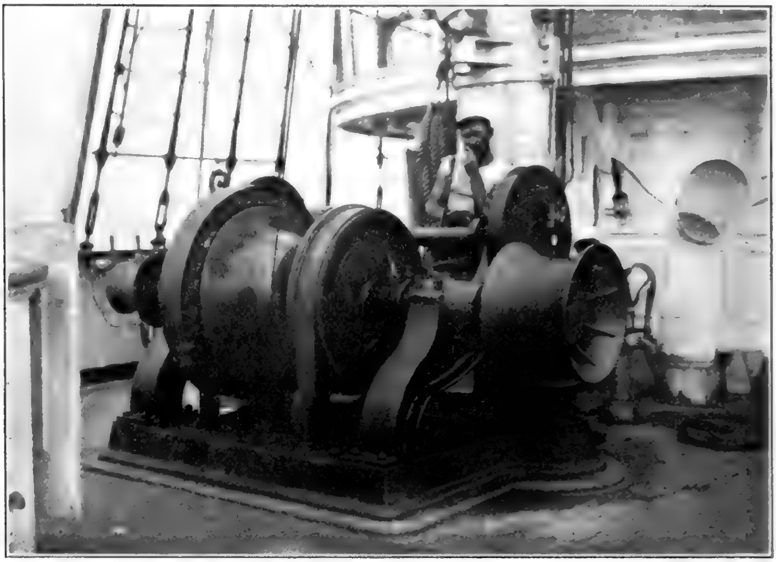
Clamped to the sounding line, a few feet above the bottom specimen cup, is a second brass cylinder used to bring up a sample of the water from the bottom to be tested for its specific gravity. The water bottle is sent down with its valves open, but on being hauled up, the reversed motion of the water against the blades of a propeller-like wheel tightly screws up the valves, and a pint or so of water from the very bottom is brought up through a depth of several hundreds or even thousands of fathoms.

A thermometer in a brass case is also clamped to the sounding line above the water bottle. This is sent down right end up, but on starting back to the surface, a water wheel, similar to that used to close the valves of the water bottle, unscrews a catch holding one end of the thermometer, while the other end is fastened by a loose pin, thus upsetting the instrument, which is now brought to the surface with the mercury in the same position as when it left the bottom. At the same time that the sounding is being made, a specimen of the water at the surface is taken, which is also tested for its temperature and density for comparison with the density of the bottom specimen.

For depths under a hundred fathoms, a hand sounding machine with a light cotton line is used, to which the usual instruments may be attached, unless the navigator wishes merely to determine his position with respect to some shoal. In this case a long weight with a hollow in its end filled with tallow is used, and enough sand or mud sticks to the tallow to indicate the character of the bottom.

On account of cross currents below the surface and on account of the drifting of the ship with the surface currents or the wind, taking a sounding is often extremely difficult, especially if at any great depth, when it requires that the ship be held in one position for several hours. Not infrequently, in spite of the greatest care, the sounding line goes down obliquely instead of perpendicularly and comes across the edge of the rudder or a propeller blade, or a kink is thrown into the line, which causes the wire to snap off at once, and the whole set of instruments is lost. The deepest sounding made from the *Albatross*, while on her Philippine cruise, was in the Sulu Sea at a depth of over 2,200 fathoms. Several successful dredge hauls have been made at depths of over a thousand fathoms, but most of the work has been done in water less than five hundred fathoms deep among the depressions and along the edges of the partially submerged plateau which forms the Philippine archipelago.

The dredging apparatus carried by the *Albatross* is of two sorts, the dredges which are dragged over the bottom and the intermediate nets which are trawled between the surface and the bottom. Of the



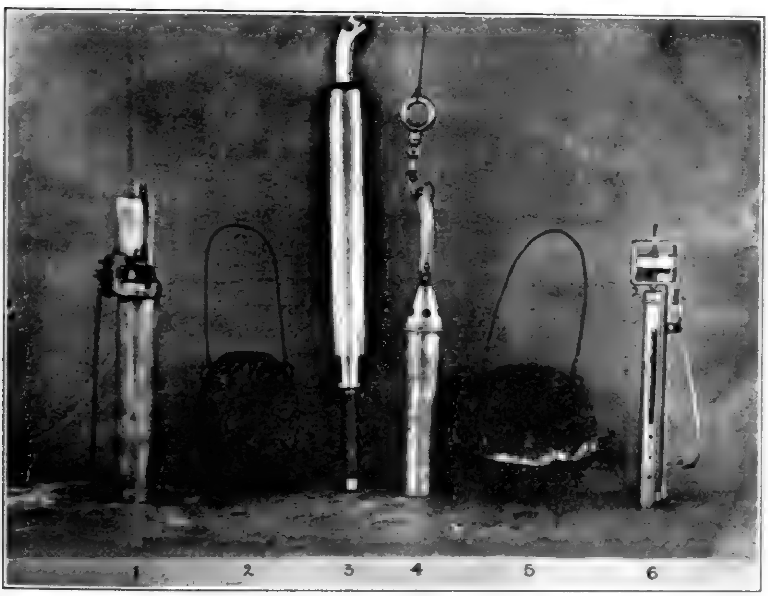
THE DREDGING WINCH ON THE FORWARD DECK OF THE "ALBATROSS."
(Photograph by DeLong.)

several models of dredges, those designed by Captain Z. L. Tanner, the first captain of the *Albatross,* and by Professor Alexander Agassiz, have been used most frequently. These consist of a pair of heavy iron running frames at the sides of the mouth of the dredge, connected with one cross bar ten or twelve feet long in the Tanner model, and by two such bars in the Agassiz type. Lashed to this frame is a cone-shaped bag, twenty or thirty feet long, made of heavy webbing, with much finer meshes near the tail than near the mouth, and with a lining of fine webbing in the after part of the bag, the end being closed by a lashing. An extra-heavy, six-foot dredge, fitted with strong teeth on the lower beam, was also built for raking over the pearl oyster beds in the southern part of the archipelago, and this small dredge has also been used to good advantage in collecting over other unusually rough bottoms.

During the Philippine cruise, the largest beam-trawl ever used by the *Albatross* was made by connecting the usual iron runners with twenty-five-foot spars, and lashing to these a bag over sixty feet long. This net was handled with great success on a smooth ocean floor until, while dredging in Batangas Bay on Washington's Birthday, 1909, the dredge caught on some obstruction and, after a moment of severe tension, gave way. When the wreck was brought to the surface, it was found that both of the heavy pine spars had been snapped in two, and that only a few shreds of the long bag were left hanging to the remains of the frame. This, indeed, is the fate of many a good, deep-sea dredge.

Two models of nets have been used for trawling between the surface and the bottom. One consisted of a heavily weighted ten-foot iron ring to which was lashed a lined bag of fine mesh. This net was wrecked in a typhoon encountered off the coast of northern Luzon, as it stood lashed to the fore rigging, and was replaced by a net of Norwegian model. The bag of the latter was made with a shear board at each corner of its triangular mouth, set so as to draw the net down as it was towed, and at the same time to hold the mouth open for thirty feet on a side.

These dredges and tow nets are put over the starboard side of the ship by a heavy boom swung from the foremast. The steel dredging cable, five or six thousand fathoms of which are wound on a huge drum on the berth-deck below, passes over a sheave at the heel of this boom so geared as to indicate upon a dial the number of fathoms of cable paid out. To relieve the severe tension on the dredging cable, which often amounts to four or five tons, two sets of rubber buffers are inserted in the rigging of the boom. One of these, fastened perpendicularly to the foremast, moves a pointer over a scale, indicating roughly in tons the strain upon the cable. Fisherman's luck prevails on the *Albatross,* as elsewhere, and often the dredge is brought to the surface with a great hole torn in the side; or occasionally the whole bag gives way under a big load as the dredge is being lifted aboard, and the collector sees all his expected treasures float rapidly astern or disappear into the dark blue water beneath the ship.



A SET OF SOUNDING INSTRUMENTS. 1, water bottle; 2, thirty-five-pound shot; 3, Thompson bail-cutting sounding rod; 4, bottom specimen cup; 5, sixty-pound shot; 6, deep-sea thermometer. (Photograph by DeLong.)

Professor C. A. Kofoid, of the University of California, has designed a small, surface tow net, made of fine bolting silk, to collect the swarms of minute animals—salpæ, medusæ, arthropoda and the metamorphic forms of other groups—which are always found at the surface of the open sea or a few feet below it. While making a bottom haul, this small net is usually towed from the ship's side for half an hour, and the contents are washed out into a jar as a gelatinous, unrecognizable mass to be sorted over in the laboratory at Washington later.

Much of the collecting work of the *Albatross* has been done along clear beaches and in rivers with seines drawn by a crew of six or eight men. The boat used on these expeditions is a round-bottomed, keelless shell of Norwegian model, called a "praam," a craft which is easily held against currents, but which drifts readily with the wind, and which shows on the whole a more unmanageable disposition than any other of the ship's small boats, until one has learned how to trim the boat and to pull it with even oar. Then one realizes how well suited this boat is for knocking about in swamps and rivers and on the beaches.

But more sweeping than any of these other methods of collecting is dynamiting the fish which congregate in great numbers on the coral reefs. Peering through a water glass, or glass-bottomed bucket, over the stern of a small boat, one plants a shot which is exploded by an electric fuse. The fish are either stunned or killed by the explosion and rise to the surface, dotting it with flecks of red, green, yellow, or chocolate brown. Many more fish sink to the bottom, the degree of the congestion of the internal organs due to the explosion and the bursting of the swim-bladder apparently causing the fish to sink. Amid more or less excitement the fish on the surface are speedily gathered in and the boat devotes itself to the more prosaic work of picking up the fish on the bottom with the aid of the water glass and an unweildy bamboo spear. Although one can not but regret the waste of many fish killed by dynamite for every specimen sent to the museum, this method is justified because it is the only means by which many species can possibly be taken, which must otherwise remain unknown.

There is, however, one small wrasse fish (*Labroides paradiseus* Bleeker) about as long as one's finger, which fearlessly flaunts its dark blue tail among the coral branches as the dynamite shot is being placed, and which even more saucily hovers near the jagged and broken coral after the shot has been fired. One's pride in his catch is humbled still further on meeting a silent, half-naked native poling his flimsy bamboo raft homeward with his basket filled with fish similar to those in the dynamite boat. The native has taken his fish in the early morning, before the breeze has ruffled the surface of the bay, without the help of dynamite or of water glass, and with only a slender, iron-tipped spear of his own rude contriving with which he has speared his fish alive.

The dynamiting work is, perhaps, the most fascinating of the collecting activities of the *Albatross.* Through the small, square, pane of the water glass, one sees the rough and jagged ledge of coral, gray or brown in the background, with encrusting forms of blue, purple, sea-green, brown, orange and varying shades of red and pink. The ledge is shattered and honeycombed into an intricate maze of crevices and pinnacles—a broken and rugged floor mottled with irregular patches of color. Huge masses of fluffy, gray soft-coral are mingled with beds of crinoids moving their long, chrysanthemum-like arms to and fro with the ground motion of the swell. Points of rock protrude among these uneven garden plots or are partially hidden by the waving masses of hydroids. Here, a delicate sea-fan stands erect upon a rocky corner; a spotted crab runs from one hiding place to another; and a great, blue starfish sprawls over a bare rock. There, a sea-cucumber, like a stout serpent, halts in the middle of a patch of sand; and among the rocks rest the giant clams with their wide open velvety mouths. A cluster of little anemones gaze upward in astonishment, and a sea-urchin huddles into a crack, like a porcupine searching for grubs among logs.

The coral usually grows out from the shore as a fringing reef, often forming a table or a coral shelf with only a few feet of water above it, and ending abruptly in a coral cliff. There are found the most luxuriant growths, as the bottom rapidly recedes from a depth of one or two fathoms to a depth of ten or fifteen fathoms, beyond which the eye, aided even with the water glass and the brightest sunlight, can not penetrate. These are the reefs of solid coral formation.

Around other islands, the coral is merely an incrustation on the rocky ledges which form the island. Occasionally a locality is found like that of the volcanic island of Kagayan Sulu, where the coral which once flourished has been killed, possibly by some change in the ocean currents or by a volcanic uplift of the island. The finer structures have been worn away and the bases of the clumps of coral stone are now covered with the slime of a fine, brown alga.

The next reef visited may be farther up the bay and bear a character very different from that of the reefs on the exposed points. Huge, goblet-shaped sponges of a living gray color stand up motionless on their thick stalks between great tables of spiny coral borne on pedestals, each little spine on these tables looking like one of the trees on a wide, pine-forested plateau. Beautiful brown plate corals and shelf corals hang along the walls of the ledges.

Another type of coral, growing sparsely over a sandy bed, may be the last representative of the coral animal to be found well inside the bay. The growth consists of hedges and patches of the diffuse and intricate tangle of branching, stag-horn corals. Scattered among the brown sea-grasses between these hedges which parallel the shore are solid head corals, large and small, fluted and knobbed, and often with their somber colors of brown and gray suggesting the head of some ancient monk half buried in the sands, while the coral branches still bear upon their tips the brilliant purple of the priest's altar robes.

It is a quiet scene. There is no glare. The colors are clear and living. It is a garden of animals, but few of which are capable of motion, though the currents and waves carry some of the slender forms to and fro in a semblance of voluntary activity. Other forms rigidly keep their one position. Never a sound is heard from these depths. Never comes a perfume or an odor from this garden. If we pluck one of these flowers from its home, it collapses and fades. We are allowed a glimpse of this new world, but never an approach into it, and we are left to marvel at Nature's lavish extravagance in creating life.

The active denizens of this luxuriant garden are the fish that dart from clump to clump of coral, or prowl among the broken rocks, or hover in swarms about some, single coral head, or listlessly rest in the hollows of the bottom. The bright colors of tropical fish are well known. Red, blue, green and yellow are painted on them in intricate and bizarre patterns. More striking even than their surroundings, most of these fish apparently do not seek protection by inconspicuous coloration. The reef fish form a class by themselves. Once in a while, a gray shark helps himself to the spoils after the disturbance of the dynamite shot has been forgotten; a sea-turtle flaps his way under the boat and, rising to the surface fifty yards away, thrusts his crooked head and neck out of the water for a more careful scrutiny of the intruder; and an eel searches through the holes in the coral or gracefully waves his ribbon-like form over the ledge into the next submarine gorge.

The patient drawing of the seine along the beaches yields an entirely different group of fish, most of them slender, swift swimmers and light or silvery in color. In the tide pools left among the rocks, are found grotesque little scorpion fishes and blennies and gobies. The seining party usually divides its time between the beach and a small river the tidal portion of which winds its tortuous way through a monotonous mangrove swamp. As the boat is pulled between the glistening, green hedges of mangrove trees which line the sluggish, muddy water-way, even the hum of gnats and mosquitoes, the harsh cry of a bird, the snapping of the oysters and clams in the mud left uncovered by the receding tide, and the occasional splash of a big lizard dropping into the water, add to the solitude of the dismal waste. In the southern party of the archipelago almost every bay and inlet is partly filled with mangroves and they often form a fringe three of four miles wide along the shore.

The results from dredging cover almost the full range of the marine animal kingdom. There is usually a great quantity of mud in the net, much of which can be washed out by towing the net at the surface of the sea for a few minutes. After the net is swung aboard, the load is dropped on the gratings of the washing table by taking off the lashing around the end of the net, and the hose is turned on to wash the mud away from the specimens. Most of these fish of the deep-sea are small but strange enough in comparison with the surface fish. Many are slate colored; a few partake of reddish brown; and some are inky black with a row of phosphorescent spots along each side which, in the utter darkness of their native depths, must glow like the portholes of a steamer at night. The other specimens in the net may show that the dredge has been drawn through a bed of siliceous sponges, of crinoids, or of Venus's flower baskets, or through a multitude of starfishes and sea-urchins. Still other dredge loads may yield small sea-snails and bivalves, weak and awkward spider crabs and many smaller crabs, the omnipresent shrimp, a few sea-cucumbers, squids, basket-stars, sand-dollars, beautiful sea-fans, hydroids and solitary corals, with jelly fish probably from intermediate depths. In the crevices of pieces of coral and sponge broken off by the dredge, are also found numbers of tiny fish, small crabs and worms. Finally, samples of the sand and shell fragments are dried and taken for specimens.

The routine of the dredging is sometimes broken by fishing for sharks with hook and line from the ship's side. Several blocks and chips of wood, which had been thrown overboard a few hours before, were taken from the stomach of one shark caught in this way, together with scraps from the ship's galley. Once a few small whales were seen spouting among the dazzling ripples of the early morning; and schools of porpoises have often lumbered past the ship, their huge bodies tumbling over and over one another in short, low curves.

In the evening, while the strains of the ship's phonograph and the thrumming of a Filipino mandolin or guitar drift back from the fore-ward deck, the fishing gear is brought out again, if the water at the anchorage is quiet, and often most interesting results are obtained by scooping up with a fine meshed dip-net the hundreds of little creatures which are attracted to a submarine electric light. Not only such fish as herrings, anchovies and half-beaks, with now and then an excited flying-fish, but many squids darting back and forth more swiftly than the fish, small crustaceans, jelly-fishes and phosphorescent worms are taken; and sometimes a water snake writhes across the edge of the outer shadow, or the dark form of a shark glides under the vessel.

The work of the *Albatross* has been thorough along the line which has been her specialty on this cruise. It is seldom that any region can be carefully surveyed by an expedition carrying the equipment of the *Albatross* and detailed for so long a time as this ship has been to the study of the fish and the fishery resources of so rich a collecting ground as the waters of the Philippine Islands. Still, this work has been that of a collector only, and its economic value will not appear until these results have been used for the greater development of the remarkable fishery resources of these islands than the native fisherman now make of them. These are fishermen who catch fish principally for the supply of the local community; who use for food nearly every kind of fish which is caught, with but little care for possible by-products; and who now preserve the fish, if at all, only by the crudest methods. Aside from the purely scientific additions to knowledge, the results of this Philippine expedition of the *Albatross* contain material which should benefit not only the fishermen as a class and many a Filipino who already uses fish as a staple article of his diet, but also a great number of the population, living inland from the coast, to whom the best species of fish properly cured would be a welcome and a wholesome addition to an often too restricted fare.

THE STORY OF A KING AND QUEEN

By Professor CYRIL G. HOPKINS
University of Illinois

ONCE upon a time a young king started out to find a better country and a better people. He had been born and raised among the common children of his country, but none of them suspected him to be a king. Even he himself scarcely realized his royal birth, and never guessed the golden harvest that one day would be his after he had really discovered his own country and established his rule over it.

So eager was he to find his kingdom and the people he was to rule over that he set out even before he was fully grown, and like all good travelers followed the sun westward, leaving behind the rugged hill-sides where as a child he had lived near the great sea.

Westward, ever westward, the young king traveled, and once he thought he had found his land and his people beyond the mountains in the valley of the Great Miami;[1] but he soon learned that he was to rule a larger kingdom in a greater country still nearer the setting sun. And as he wandered on, he came, at last, to the Land of the Illini[2] which stretched away farther than the eye could see, a broad expanse of almost unbroken prairie land.

"This," said he, "is my country, here will I prosper, here will I be happy, and here will I stay and establish my kingdom." The young king found an ideal home for himself on this dark prairie soil, and for many years he lived as a very independent bachelor; but there finally came a time when the supply of food which he had found already prepared in the soil became partially exhausted, and in hunger he said to himself. "It is not good for man to be alone." He then sought a princess named "Clover," and thereafter always rejoiced that she consented to be his queen. Where she prepared the soil, King Corn was again as well fed as ever.

Queen Clover found that the supply of food in the soil had not been completely exhausted during King Corn's life as a bachelor, but only that the supply of some ready prepared foodstuffs was much depleted, and from the remaining total supply of raw materials she was able to prepare much food fit for the king's use, and she was also able to prepare the king's bed in the soil as it had never before been prepared for him.

Years passed, and they were happy and prosperous years; but finally

[1] The Miami Valley in Ohio.

[2] Illini is the Indian name for Illinois, which means the land of men.

both Corn and Clover were forced to remember the ancient saying: "And this, too, shall pass away." King Corn began to complain again that his bed was getting hard and that the food furnished him was not sufficient. Queen Clover replied that she, too, was suffering from hunger, and that her home in the soil which had always been sweet and clean was becoming sour.

Naturally, Queen Clover was much more sensitive to this condition than King Corn, but she had done the best she could with what she had found in the soil and she had also secured for herself one choice kind of food from the air, and even prepared it for the King so far as she could.

But, in spite of all they could do, Queeen Clover's health began to fail; and some years she was entirely helpless, and consequently King Corn suffered greatly. They consulted many doctors. Some said the soil needed more drainage; others said the seed-bed should be better prepared; and still others advised the use of better seed and of more thorough cultivation.

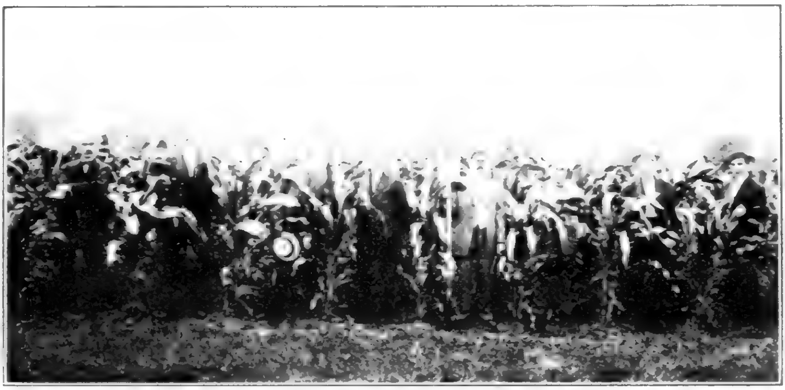
All of these remedies proved helpful, but they afforded only temporary relief. At last Queen Clover said to the king that when she was a child a doctor, whose name was Science, had once visited her family, and that whatever he did was exactly right because his knowledge was true and absolute. He had shown them that all of the members of the Clover family were able to secure nitrogen from the air, and that this was one of the essential foods for plants.

The king and queen were greatly rejoiced to learn that the old doctor was still living, and they at once secured his services.

After a thorough investigation of the conditions, Doctor Science reported that he understood the case and that the remedy was simple and still within easy reach, but that they should proceed at once to apply the treatment before it became too late.

"The fundamental trouble," said he to King Corn, "is with the soil in which you live. In order to establish a permanent and healthful home for yourself and Queen Clover, about one half ton per acre of pure steamed bone meal, or of fine-ground natural rock phosphate, and two tons per acre of ground limestone should be applied once every four or five years. Then don't occupy the land too much of the time yourself, but bring in other crops and have a rotation—such as corn, oats and clover, or corn, wheat and clover for a three-year rotation; or wheat, corn, oats and clover (in grain farming), or corn, corn, oats and clover (in live-stock farming), for a four-year rotation. In the four-year rotation for grain farming a catch crop of clover may also be seeded on the wheat ground and plowed under the next spring for corn, and the regular clover crop in the fourth year may be mowed once or twice and left lying on the land, the seed crop afterward being harvested with a buncher attached to the mower.

1909 CORN, WHERE THE CLOVER AND ALL CROPS ARE REMOVED AND NO TREATMENT APPLIED; yield 35 bushels per acre.



1909 CORN, WHERE CLOVER AND CROP RESIDUES ARE PLOWED UNDER AND LIMESTONE AND PHOSPHORUS APPLIED; yield, 79 bushels per acre.

1909 CORN, WHERE MANURE, LIMESTONE AND PHOSPHORUS ARE APPLIED; yield, 86 bushels per acre.

"In grain farming, only grain or seed should be sold from the farm, all clover, straw and stalks being returned to the land in order to maintain the supply of organic matter and nitrogen, which are just as important as limestone and phosphorus;[3] and in live-stock farming all produce should be used for feed and bedding and all manure carefully saved and returned to the land, preferably within a day or two after it is produced, in order to prevent the waste of plant food."

"Now, do you understand all this?" asked the old Doctor.

"I don't," replied King Corn.

"And I don't," added Queen Clover, "but I have faith in Doctor Science, and I think we should follow his prescription. I know very well that I can't do as much as has been expected of me in the past. I can't make food out of nothing, and the king can't live on just air and water; and the soil is becoming so worn and hard that I can't even make a good bed for him, especially when I'm half starved myself most of the time."

King Corn agreed to this. He had long supposed that Queen Clover could get from the soil and air all of the food they would ever need, but he now remembered how he himself had failed in this as a bachelor, and he felt that Clover had been such a good queen that anything which Doctor Science prescribed should be provided, because above all else he desired to have the queen restored to health and happiness, for he did not care to try to live without her again. On the other hand, they both agreed that they would test the doctor's prescription on part of the land on which they lived and have also some land without such treatment, in order to compare the results.

There were three very uniform fields of typical prairie land which had been in permanent pasture for many years, but on which King Corn had recently lived for three years in succession, and they had produced for him as an average of those years the following yields:

Field A	63 bushels per acre.
Field B	63 bushels per acre.
Field C	66 bushels per acre.

They were now sown for three years to oats, clover and cowpeas, after which each field was divided into three parts and, in accordance with the advice of Doctor Science, limestone and phosphorus were applied, not to all of the fields, however, because a test was to be made of the treatment. Thus no treatment was applied to Field A; limestone alone was applied to Field B, and both limestone and phosphorus to Field C. On all three fields the second crop of clover was plowed under just in proportion to what grew on the land, and in the later years the corn stalks,

[3] Phosphorus is the valuable element of plant food contained in natural rock phosphate and also in bones, and large amounts of phosphorus are required for clover as well as for corn and other crops.

oat straw, and all clover hay and straw were returned to the same fields on which they grew, thus following finally the complete prescription.

A regular three-year rotation was also begun, one third of each field being in corn, one third in oats, and one third in clover, each year; and the next year, corn followed the clover, clover followed the oats, and oats followed the corn.

As an average of the three years, when only partial treatment was used, the yields were as follows:

Field A	67 bushels.
Field B	69 bushels (with limestone applied).
Field C	74 bushels (with limestone and phosphorus).

As an average of these three years, compared with the former record, it was seen that the yield was 4 bushels higher on Field A, 6 bushels higher on Field B, and 8 bushels higher on Field C.

"I think I feel somewhat better," said the King, "and I should like to continue the treatment at least for a few more years."

The oat crop followed corn and thus Queen Clover was compelled to sit at the third table in the rotation, and she had had the full benefit of the limestone and phosphorus for only one year; so she was glad to have a further chance to try the treatment.

As an average of the next six years, the yields per acre of corn were as follows:

Field A	63 bushels.
Field B	67 bushels (with limestone applied).
Field C	87 bushels (with limestone and phosphorus).

At the end of these years the King had his accounts all figured up.

"Field A has gone down again," said he to the Queen. "It has lost the 4 bushels it had gained by the improved rotation."

"Yes," replied the Queen," and I don't like that field a bit. I almost starve when I try to live there, and Field B is growing poor, too."

"So I see," said the King, "by 2 bushels, although limestone has maintained the yield 4 bushels higher than Field A; and where both limestone and phosphorus are used, the average yield is 24 bushels better than without them. That reminds me of old times, my dear. When I was a young bachelor, a yield of 87 bushels per acre was not uncommon."

"You might try 'baching' it again," suggested Clover. "You know I'm not considered of much value, and the oat crop isn't worth very much. Surely, three crops of corn would be worth more than one each of corn, oats and clover."

"No, no," said the king. "I do not care to repeat my experience as a bachelor; and, by the way, I have never confessed to you the real condition I was in when you consented to be my queen. The facts are that

I lived on one field for thirty-one consecutive years, and as an average of the last six years the yield was only 23 bushels per acre. Thus it required three years to produce 69 bushels, whereas 87 bushels are now produced in one year under this system of permanent soil improvement in grain farming; and even 90 bushels per acre are produced where limestone and phosphorus have been used in the live-stock system, which, you remember, was also suggested by Doctor Science, and which we have been trying out on Field D."

The writer also has a confession to make:

The six-year averages of 87 bushels in grain farming and of 90 bushels in live-stock farming are the records of the Illinois Agricultural Experiment Station for the last six years, 1904 to 1909.

1910 CLOVER ON THE FAIRFIELD EXPERIMENT FIELD IN SOUTHERN ILLINOIS. Manure alone (on left) supplies but little phosphorus and will not correct the soil acidity. Manure, limestone and rock phosphate (on right) produces a large yield of clean clover. (If the Corn Belt needs limestone and phosphorus, what shall we say of "Egypt"?)

During the same six years the average yield of oats was as follows:

Field A .... 48 bushels.
Field B .... 50 bushels (with limestone applied).
Field C .... 62 bushels (with limestone and phosphorus).

As an average of three years during which the second crop of clover was harvested for seed, 1907, 1908 and 1909, the yield of clover seed was as follows:

Field A .... 1.9 bushels.
Field B .... 2.1 bushels (with limestone applied).
Field C .... 2.7 bushels (with limestone and phosphorus).

As an average of the last three years, 1907, 1908 and 1909, the yield of corn on Field A was only 58 bushels, but the limestone and phosphorus together increased the yield of corn by 29 bushels, the yield of oats by 10 bushels, and the yield of clover seed by nearly one bushel per acre. The total value of these three increases is $19.40, counting 40 cents a bushel for corn, 30 cents for oats, and $6.00 a bushel for clover seed. The increase has paid for the cost of the limestone and phosphorus and given in addition a net profit of more than 100 per cent., and besides this the soil of Field C is growing richer and richer, while the soil of Field A and Field B is growing poorer and poorer.

As an average of the three years 1905, 1906 and 1907, the yield of air-dry clover hay in the first cutting was as follows:

Field A	.8 ton.
Field B	.9 ton (with limestone applied).
Field C	1.8 tons (with limestone and phosphorus).

These clover crops were harvested and removed, thus removing much more phosphorus from Field C than from A or B, but since 1907 all clover except the seed is returned to the land, on all three fields; and hence this story is to be continued.

Nota bene.—Once upon a time a young man came into what is now the heart of the Illinois Corn Belt and found the green grass growing luxuriantly upon the dark prairie soil as far as the eye could see. He had very little money, but the land looked good to him and since it could be obtained from the government at small cost he decided to buy a farm. He began to raise corn and cattle, and even though the price of those products was very low he was soon able to buy more land, and by continuing as he began he became the owner of twenty-seven thousand acres of land before his death. His children and his grandchildren are still living upon the land, which is now worth $200 an acre, even though it requires fertilizing to maintain its productiveness.

While there are eight times as many people in the United States in 1910 as there were when that young man came to McLean County, Illinois, there is now no cheap land anywhere on which corn can be grown with success and profit. Thus the farmer of the present and the farmer of the future must make his success and profit by improving the land now occupied.

THE SOCIAL PROBLEM

By Professor JOHN J. STEVENSON
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MACCHIAVELLI, discussing the choice of political ministers, grouped intellects into three classes: "one which comprehends by itself, another which appreciates what others comprehend, and a third, which neither comprehends by itself nor by the showing of others; the first is the most excellent, the second is good, the third is useless." The last class constitutes the mass in any nation. Draper put Macchiavelli's statement into terse Saxon: "The first group thinks for itself, the second thinks as others think, the third does not think at all." Every man, familiar with "practical politics," knows well that the grouping is as true for this day, and for America, as it was for Italy four centuries ago. In preparing a list of candidates for office, the third class is ignored—it will vote straight. The second class is ignored; it consists of "independents," following slavishly some men in the first group, whose opinions they respect. Those leaders must be considered, but their followers give managers no concern.

The economist is compelled to recognize a similar grouping. His first class consists of men gifted with foresight, able to plan and to execute, able, as it were, to hold the future in the grasp of the present; men of his second class possess these powers in less degree, but lack initiative or mental poise, are apt to be found wanting at critical moments, yet are capable of much as subordinates; while those of the third class are able or willing to work in very narrow paths with little or no responsibility.

In this, as in all classification, the boundaries are indefinite and gradations exist in each group. There are many in the second who, but for some defect, would have been in the first. "He might have been a statesman, if—" or "He ought to have been at the head of great enterprises, but—" are expressions only too familiar. The third class has many who possess almost every qualification for the second, but they are unwilling to undertake serious tasks, preferring to provide for the present as well as for the future by moving along lines of least resistance. Yet the grouping as a generalization is true; it is merely the assertion that differences in men are largely innate, are due only in part to environment. If a man belonging to the first group be born among the lowest of the third, he is certain, in this country, at least, to find his place as leader in politics or in other directions long before reaching middle age. The division into "classes and masses" is not of man's making; it is part of nature's economy. Men of all groups are born in all grades of society, among the rich as among the poor, and are found among the so-called educated as well as among the illiterate. A man's place depends on his natural endowments.

The vast majority of mankind consider little beyond the present; the inherent indolence can be overcome only by compulsion. The ordinary man finds that compulsion externally in the necessity of providing for immediate needs or against threatened disaster. He may have an indefinite longing for better things, but that incites him to no legitimate effort. The extraordinary man finds compulsion within; he looks far beyond the present, and desire for noteworthy reward impels him to extraordinary exertion. In practically all cases, self-interest is the compelling motive, as much to the man who demands only his daily bread as to the man who seeks an empire. Every advance in civilization, every improvement in the moral or physical condition of mankind in modern times has been due primarily to this self interest. The initiative has come from men of the highest class, who, in executing their plans have utilized men of the other classes and all have shared in the resulting advantage.

"Born leaders" become creators. Men speak of Sir Christopher Wren as the creator of St. Paul's Cathedral because that edifice existed full-formed in his mind before a stone had been quarried for the building. The great intellects, who planned the transcontinental railroads were as truly creators; they saw full-grown a mighty empire beyond the plains, which would come into being as the result of their work but which would be impossible without it. They made not only the railroads but also the empire—they created the values. And the story is the same in the development of every great industrial enterprise.

But without aid from men belonging to the second and third classes creators of values could do little. One may have abundant strength and abundant skill, but without a spade or its equivalent he can not cultivate the ground and he may starve. And just here is the prevalent confusion of ideas. Men fail to recognize the relative importance of director and directed. Some years ago, when the writer expressed admiration for the executive ability of a successful acquaintance he was surprised to learn that the compliments were undeserved. It appeared that the success was due wholly to the "O.P.W. racket," which, being interpreted, means other people's work. This successful man merely concocted business enterprises and assigned to each lieutenant a share in carrying out the plans. Further than that he did little, aside from giving occasional advice, until the time came for division of profits, when he received the largest share. Now, the men selected to look after details had become disgusted, were determined to be servants no longer and were about to strike against the manipulator who had put them all into comfortable circumstances. The story is the same throughout. The plodding farm-hand can discover no good reason why his employer should occupy a large bed downstairs while he sleeps on a narrower, less ornate couch upstairs; the laborer, who shovels cinders in a mill-yard, knows how necessary his work is to the owner's success; he is convinced that an unfair share of the profits falls to his employer as well as to the man at the rolls. The subordinate everywhere, whatever his position may be, feels that his worth is unrecognized and that his reward is insufficient; while the man outside of all, angry because he has no share whatever, eggs on the discontented, anxious only to see some one injured and hoping that the injury will be distributed in proportion to the reward received.

It is absolutely certain that cooperation of all groups is essential to completion of great projects. Without direction by a master-mind, there could be no utilization of man's labor to the advantage of all. It would be like the superfluous heat of the sun or the force of the coastal tides, each sufficient to perform the whole mechanical work of the world, yet unused and useless because no one has conceived a method of control and application. To all intents and purposes, the energy of the vast mass of mankind is merely so much mechanical force, incapable of self-direction and without utility, unless marshaled by the constructive power of some master-mind.

But without this force the master-mind would be equally helpless. The man who conceived the transcontinental railway was fettered by physical limitations; he could plan the whole undertaking, but, in in order to complete the work within the compass of a single life, he was compelled to make use of other men's powers, mental as well as physical. Among engineers, contractors, operators, the chiefs were men of his own group; but, in each department, there was gradation in responsibility until at the bottom was the indiscriminate mass of employees, handling tools mechanically.

And remuneration, throughout, is graded to accord with the responsibility. The great reward is given to one whose physical output seems to be nothing, who has few hours at the office and many hours, apparently, for relaxation. The reward decreases as hours of physical exertion increase and the minimum is given to the laborer, whose only contribution comes from muscular expenditure. Mind, not muscle, receives the chief reward. Physical labor is a tangible thing, easily comprehended by even a stupid man; whereas proper valuation of mental labor is within the comprehension only of those competent to perform it. The hewer of wood and drawer of water are not to be blamed because they think the rewards of the higher groups disproportionately great; but their discontent is not against anything of human origin; the disproportion is due to inexorable natural law, for men are born unequal, mentally, morally and physically.

And thus it is that supply and demand determine the matter. The man in position of greatest responsibility, the *vis a tergo,* naturally receives the apparently disproportionate reward, because his group is so small that to replace him is difficult; he deserves the greater part of the gain, be it money or glory, because he alone makes the gain possible. He alone can determine the gradations of responsibility among his subordinates and he assigns rewards according to the relative importance of the services and the difficulty of replacing. The pay of the mere laborer is small because it is worth no more; the supply is in excess of the demand. If at any time demand be in excess of supply, inventive genius enters at once and makes fewer laborers needed, while the work is done better, more cheaply and more expeditiously. During the Civil War, agricultural laborers could not be obtained, but the land did not remain untilled. Gang ploughs, mowing, reaping and threshing machines did the work. When vast enterprises in railway and other construction were undertaken, there was insufficient supply of brainless muscle, living picks, shovels and hods, but the steam shovel, automatic cars, hod elevators and other contrivances quickly made the supply again more than equal to the demand. Experience shows that machinery is preferable to ordinary labor; it can be depended on; its strikes are brief and are overcome quickly.

Skilled mechanics recognize the conditions. Products of even the highest type of hand labor are rarely equal to those of machinery. The hand-made watch is not so good as the watch made by machine at very much less cost. Fifty years ago the man with a trade was a capitalist; but every decade has brought about a decrease in his importance. Machinery has reduced the carpenter to a mere fitter and nail driver; the cabinet maker is little more than a handler of the glue pot and screw driver. It is the same wherever one looks; the outcome is inevitable; mere manual labor will be replaced by machinery in such measure as to render even the better members of the third class barely essential. If this is to be the outcome, what about the great mass of men able or willing to work only as mere pawns in the hands of others?

This question can not be answered in *a priori* fashion. The elements of the problem are not hypothetical, they are cold facts and their interlocking makes the whole complex almost beyond comprehension. It is certain that at present no one student will see more than a little way toward the solution.

The problem is but one part of the greater problem, the elimination of poverty. It is true that incompetents are born in all stations, but it is especially true that poverty leads to their multiplication, while it is also true that their multiplication intensifies the curse of poverty by increasing the number of those for whom the world has decreasing need. Here the problem concerns only the United States, where the young are fleeing from the farm and are flocking to the cities, already overstocked with unskilled labor of every sort. Actually, the problem concerns the cities alone; it is practically unknown elsewhere.

Those who urge that immigration should be restricted or even prohibited are told that not all immigrants are undesirable—and that is true. Pioneer immigrants from any land are apt to be the best of their race. Those who came from northwestern Europe were, mostly, uneducated and without property; but they dared leave the home of their ancestors and braved the dangers of an unknown land; they thought for themselves and worked with high aims; they made their way and they made the United States. But a very great proportion of immigrants arriving during later years have come because others have proved that the experiment is more than safe. And in too many cases they bring with them erroneous ideals of personal liberty and false conceptions respecting relations of the government to the citizen.

It has been said that this country has need of every able-bodied immigrant who is willing to work; but this a sad misconception of the conditions. Even were the incomers agriculturists there would be room for but a small number, unless all our methods were revolutionized—a process requiring a long period. The available cheap land has been taken up—were there land remaining it would be unavailable, as few of the incomers have enough money to purchase equipment for even a small farm. The assertion that agricultural laborers are in constant demand is an error; for that demand exists only during the brief period of harvest and it is decreasing each year with increasing use of machinery. The acreage of crops is greater than ever, the crops themselves are of greater magnitude than ever before; yet the agricultural population shows steady diminution because fewer workers are needed. One must recognize that there is a limit to any country's capacity to furnish work and that the limit has been reached in this land. For years, the United States could utilize half a million newcomers each year, but its ability in that direction ceased before 1906. During the remarkable building "boom" of 1905, there was not work enough in New York city for the resident bricklayers and masons. In spite of shrewd management by trades unions, there were many skilled workmen who wandered through the streets, seeking work and finding none. Even then, in the midst of superabounding prosperity, was heard the demagogue's cry that work should be supplied by the government, that the scandal might be removed. But the influx still continues; nearly 1,000,000 immigrants arrived during the first half of 1910.

There are great dangers in unrestricted immigration. If it continue, conditions here must approximate those in the crowded areas of Europe. With increasing surplus of work-seekers, wages must decrease. Severe restriction of immigration should come and come quickly. It is not the duty of those already here to impoverish themselves in an effort to support the distressed or dissatisfied of all lands. Even the golden rule does not require that a man love his neighbor better than himself; and the Apostle Paul, that champion of generosity and self-denial, asserts that whoso careth not for his own is worse than an infidel, he has denied the faith. But restriction of immigration is not enough; the surplus population is already here; our cities are overcrowded with utterly unskilled labor— it is estimated that in New York city alone there are 100,000 unemployed clerks; the great problem is already with us.

Some maintain that the problem is purely ethical; they assert that the law of supply and demand should not be considered in connection with employment; that if employers would consider properly the interests of their employees all difficulties would soon be of the past. But this is purely academic. No doubt conditions would be improved greatly in some respects if the golden rule were the standard of conduct; but it must be remembered that selfishness is not confined to employers and that the sermon should not be preached to them alone. When man's nature has been so changed that each will endeavor to do his full duty, the time will have come for essays on ethics. But as long as the employer seeks to get as much and the employee seeks to give as little as possible for the wages, discussion of the ethical side will remain academic. In any event, it is irrelevant now; it concerns only those for whom there is work; it offers no relief to the increasing number of those for whom no work exists.

The socialist has his remedies. He tells us that all men should have equality of opportunity; that no man should control another's opportunity; that every worker should receive such wages as would enable him to live in comfort according to the American standard.

The implication that opportunities are not equal in this land is so contrary to fact that one can not believe that it is made in good faith. Hardly a quarter of a century has passed since the impoverished Russian immigrants first set foot on our shore, yet they already own much of the lower east side in Manhattan and great tracts in other boroughs. It is conceded that the conditions for some kinds of unskilled labor are terribly bad; one dollar a dozen for making shirts, sixty cents a dozen for making bedspreads, tell the story of misery; but not of slavery. Such sad conditions tell only of competition for work, that awful temptation to the selfishness of employers and of purchasers; they tell only that there are too many workers and too little work; but they do not lead to the suggestion that there should be no employers. And one must ask what would be the advantage if wages were raised to the "American" standard while work would be provided for only a part of those seeking it. Increased wages of those at work would only increase the misery of those without it, by increasing the cost of living. To be satisfied respecting the relation of wages to cost, one need only compare the prices and wages of 1896 with those of 1910.

All of these suggestions ignore some essential elements of the problem. There can be no relief so long as the more or less incompetent and improvident class remains as the preponderating element in our urban population. It is well known that at present births are more numerous in the poorer than in the better parts of cities and that the more or less dependent class increases with great rapidity. As long as this condition continues all suggestions for improvement will be worthless. The first aim must be to prevent multiplication of the class born to poverty.

When one advocates restriction of marriage, he finds himself face to face with bitter opposition based partly on sentimental notions, partly on supposed religious grounds and partly on inherited conceptions. He is told that marriage is a sacred thing; that reproduction is one of life's great duties, for God told Adam and Eve to be fruitful and to replenish the earth; and he is warned that by placing restrictions on marriage the community would encourage immorality.

The reference to Adam and Eve is hardly relevant to conditions of this day. If they were the only pair, they certainly had no reason to fear for the future; the world was theirs and there was ample provision for abundant progeny. They were in excellent physical condition and, being thoroughly repentent, they were well-fitted morally for parental responsibility. The plea that marriage is a sacred thing with which the state may not meddle is unimportant. The state does meddle and does regulate; even the Mosaic civil law regulated it; and the limit to which the state may go in regulation must be determined only by what is demanded for protection of the community. The plea that marriage is a sacred thing is made by the same pleaders who praise marriage as preventing "immorality"—not a very exalted conception of the purpose of marriage. But judging from reports of surgeons, there is no great room for increase of the vice, euphemistically termed "immorality"; but even if there were, the community would not be responsible for the result, any more than it is responsible for burglary and theft because it recognizes individual ownership of property. On the other hand, by permitting practically unrestricted marriage, it is guilty of encouraging still greater evil, the growth of a shiftless, feeble class with tendency to criminal ways and with prospect of little happiness.

Much has been said and written recently in favor of large families and the cry is against race suicide. One is told that the early settlers of this land had large families and that the children were strong, physically and mentally. But they were a fine stock, and, like all pioneers, they were the best of their race—and natural selection came to their aid. Sheltered in only too well-ventilated houses and exposed to a severe climate, the feeble perished in infancy, the strong survived. No such selection exists in the class under consideration, which, unfortunately, lacks the original physique. More than that. Pure food laws, sewerage, proper construction of houses, sanitary regulations and the rest antagonize the operations of natural laws, whereby the sins of the parents are visited upon the children. Those who, under former conditions, would have died in infancy now survive the perils of the earliest years, in increasing proportions reach maturity, marry and reproduce themselves—a menace to the health and well-being of the community. The reports of surgeons employed by the New York Board of Education prove that a great part of the children in some portions of the city suffer from congenital defects, which, uncorrected by surgical treatment, lead to mental as well as moral deficiency; while teachers have discovered that much of the mental obtuseness observed in pupils is due to lack of proper nourishment. Quality, not quantity is all important in a population. It is said that a nation with stationary or decreasing population is in decadence and much ado has been made over the sad condition of France. Yet the thoughtful Frenchman is prompt to remark that he prefers 35,000,000 healthy, well-fed and contented Frenchmen to 100,000,000 of wretched Russians. It is true that in France war material is not increasing so rapidly as in some other lands; but the civilized world is outgrowing the notion that men should be bred as horses, to be killed in settlement of disputes which do not concern them.

It may be well enough for wandering savages, such as the Australian aborigines, to multiply heedlessly like rabbits and weeds, but it is not well enough in civilized lands where masses congregate in cities and the food problem becomes complex. Philanthropists, as they think themselves, would not prevent the multiplication of children, for that is a natural right of which man may not be deprived, even though he can not provide food for his offspring. The "cry of the child" is made the basis of bitter attacks on the constitution of society and demands are made that the state, whatever that may mean, should not only protect but also provide for needy children. In recent months, the pensioning of mothers left with children has been urged as the community's duty. An association for aid of the poor lately published in its annual report the picture of a despairing man sitting by the bedside of his wife and her newly born infant, with the query below, "And what will he do with the sixth?" A missionary out west with seven children and a salary of $400 a year, awakened the deep sympathy of a women's missionary society. But the question arises at once and it will not down, Why should that helpless poverty-stricken man and wife have had a sixth? Why should that poverty-stricken home missionary have had seven? More than that—why should either of them have had any?

Philanthropic work, in endeavoring to ameliorate the pangs of poverty, begins at the wrong end; instead of trying to abolish poverty, it labors incessantly to increase it and its burdens. The improvident class procreates recklessly and would-be philanthropists encourage the folly. They are like men in a plague-stricken town, who endeavor to ease the pain of sufferers but refuse to recognize and to remove the sources of disease. Tenements are made better every year to protect the careless against their own negligence; public schools are inspected that contagious diseases may be checked; vaccination is compulsory and free; great dispensaries provide free treatment for all comers; women in confinement have free medical attendance and diet kitchens provide proper food for them; infants are cared for in day nurseries for a nominal sum that the mothers may go out to work; education, even professional education is offered to all, without cost. There is free treatment in the schools for children with diseases of the throat, nose and ears; effort has been made to secure in the New York schools free luncheons, free spectacles and free dental service for children who appear to need them; and it is reported that in the Chicago schools a fair beginning has been made, in that food for hungry children is provided at nominal cost.

Everything within the range of possibility has been suggested or attempted in order to free the improvident from all sense of responsibility for their offspring. Yet those who are guilty of this sin are the same with those who regale the community with illustrated lectures on the horrors of the slums. Philanthropy should begin its work at the other end; instead of endeavoring to alleviate the condition it should endeavor to abolish it. Instead of merely lamenting the fact that sewing-women's wages are so pitifully low, it should try to prevent increase of competitors for work, that wages may be better for the next generation. Instead of encouraging heedless procreation, its efforts should be to encourage restriction. The duty of parents to children should be made plain to those who are unwilling to recognize them; and indiscriminate free medical treatment should be abolished. Laws against child labor should be made more stringent and should be enforced rigorously; farming out of children should be made impossible. When it has been discovered that the community will not bear the expense there will be hesitation, and marriage of those without prospect of subsistence will be less frequent. Marriage of persons mentally or physically defective should be illegal and increase of the criminal or vicious should be made impossible by aid of the surgeon. With smaller families, with better surroundings, all could be well fed and conditions favoring degeneracy in the young would be reduced to the minimum. This is not to say that only those in independent circumstances should marry; with constantly improving sanitary conditions everywhere and with work for all competent to perform it, the average expectation of life for a sound man would be itself a large capital.

It is true that restriction of immigration and severe regulation of marriage would not abolish poverty; the poor will be with us alway. Disease and disaster are liable to befal the best of men; temperamental differences will continue and men and women without good sense will be found everywhere. The dependent and vicious class will not disappear while the earth lasts. But the community would have done its best in one direction, at least, to prevent any but that unavoidable poverty, which demands not only sympathy but also beneficence.

MOTOR EDUCATION FOR THE CHILD

BY J. MADISON TAYLOR, A.B., M.D.

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OPPORTUNITY is too often regarded, by parents and educators, as the equivalent of training. Many confident assertions are made to the effect that enforced educative measures for the very young child make for harm, and that spontaneity can be depended on to direct and sustain impulse. This would be true, perhaps, if parental wisdom could be relied on to provide thoroughly wholesome environment, normal suggestion and stimulus to varied activities.

Unfortunately, children are compelled to adapt themselves to diversities in environment which, in comparison to that of most domestic animals, is profoundly to their disadvantage. Problems of child-growth should be considered in the light afforded by customs prevailing among breeders of valuable animals. Among animals the young one is welcomed and the mother devotes herself almost wholly to its best interests, at least during the critical period of lactation and dependence. Thus an invaluable start is secured in the right direction, both in nutrition and in habit formation. How deplorably different are the duties of maternity as viewed by the large majority of human mothers only those of us who have spent years in the dispensaries for sick children, or have had other direct experience of the poor, can fully appreciate. The laborer must have his family near him because his home must be near his work. Small consideration is given to the problems of infants and youngsters who follow in the wake of household necessities.

Among breeders of animals the young ones are of paramount importance. They constitute direct assets and the utmost effort is given to develop them into salable products. The human mother must primarily serve as cook and purveyor of creature comforts to the wage-earning father. The animal mother gives her undivided attention to her offspring till it is able to act alone in accordance with its relatively higher capacity for independent functionation. Hence it is obviously important that at the earliest possible stage of human existence the individual shall be supplied with not only the best opportunities available, but intelligent guidance in motor development, in order that it shall maintain its sovereignty over animals, or itself become an efficient animal.

Fortunately, many human mothers are supplied with reliable instincts and solicitudes. The exigencies of city life tend overwhelmingly to vitiate primitive impulses, to subordinate such desires and capacities as make for development of the home; to change the nest, or the hearth-stone, into a mere abiding-place, whence the least as well as the greatest must fare forth to earn money for necessities, or, it may be, for useless luxuries. It is true, the best motor education is supplied in the ideal home, on howsoever humble a basis, as that of the pioneer, the farm laborer, the small farmer. Here there is a constant supply of normal stimuli to action, made convenient and necessary by communal interests. Each one, to the youngest child, is called upon to do such things as lie within its capabilities, thus contributing proportionally to the common welfare. This, in its better aspects, can not be surpassed as an educative groundwork. The poorer city dweller, subsisting on ready-made foods and with no outdoors but the street, finds no scope for the primitive actions of digging, chopping wood, carrying water, hence can not develop symmetrically. Even among the well-to-do things are little better. The street, with its many perils from "devil-wagons," trolley cars, etc., is becoming more and more unfit for a playground. The schoolhouse yards sometimes provide space wherein the scholars can give vent to motor impulses, but at best these are wholly inadequate. Even the very rich city dweller is poor in opportunities in comparison with the country child, who has access to a bit of woodland and a farm-yard.

Look at any lot of city school children and you will find, with only moderate scrutinizing, a pitiable array of asymmetries, local weaknesses, evidences of inadequate development. They are handicapped from the cradle; weighed down with damaging tendencies to stoop, to slouch, to impair the chest, in which the heart and lungs must have space; to tilt downward the pelvis, which is the key to the nutritive organs.

No fuller argument is needed to establish my contention that all children, especially those of the cities, require not only ample opportunities to expand and develop, especially by exercise, as in plays and games, but also specific motor training to correct the perpetual tendency to minor deformities.

The most thorough method of acquiring both mental and physical efficiency is by systematic motor education. We may then outline how this can best be achieved. Always the play impulse should be encouraged. Amusement-games alone, however, often lead to listlessness, spiritlessness, impassivity, aimlessness, at best but negative qualities. Competitive games accomplish much more where there are able leaders to animate and direct action. The most educative factor is to stimulate the motor centers by enforcing precision of movement. A few exact movements conscientiously performed accomplish more for accurate coordination than hours of listless, half-hearted movements. Routine, monotony, repetitions, weary minds and fatigue bodies. Always it is the degree of spontaneity, the heartiness of response, the candor of cooperation, which make for progressive invigoration.

Hence the ideal educational agency, not only of gross motion, but those modifications of motion, reaction-times, accuracy in eye, ear, voice, decisions, etc., is the game of ball and bat, or mimicries of chase and war, and such like spontaneous impulses to do, to fight, to achieve.

Many modifications can be made for the extremely young of either sex, *e. g.*, bean-bags, pillow fights, up to the medicine-ball, basket-ball, base-ball and cricket. All exercises of quickness and precision are exhaustive; hence they can not, or should not be unduly prolonged for the very young.

One of the best means of motor education is seldom employed in this country. This is training in posing, in imitating classical statues. My friend M. Laussat Geylin told me of an interesting competition he witnessed in a provincial French town. The teacher by this charming device trained a class of young peasants to such a point of physical excellence that they took a national prize. The plan is well worthy of wide imitation. Reflect for a moment how perfectly the essential conditions of balance, precision, full excursus, tension, steadiness, stretching, are thus graphically exemplified. Take the Discus Thrower, the Fighting Gladiator, the group of the Laocoon for extreme types of force; the quieter attitudes even require much of vigorous poising. D. A. Sargeant has written a book advocating the forceful simulation of a variety of common acts—rope pulling, javelin throwing, etc.

Vanity, always a powerful stimulus, is thus strongly elicited. The simpler Greek exercises were unsurpassed for inducing symmetry, especially when each side of the body was equally employed, *e. g.*, javelin throwing right and left, so too of the discus.

Always the left hand should be trained equally with the right, at least in educational measures. There is too much one-sidedness encouraged in tennis, golf, baseball, etc.

There may be objections to little tots attempting boxing or fencing, but it is entirely feasible and distinctly valuable for even young children to be taught wrestling. By single-stick exercises, symmetrically, I have entirely cured the effects of chorea, descending atrophy from cerebral paralysis, and the disablement of poliomyelitis.

Then again, the power and precision which follows resisting-exercises as taught by the Swedes (or better, as elaborated by a wonderful mulatto, Jeremiah Davis, who taught me amplifications of this rather tepid procedure) are really marvelous. Closely allied to this is the jiu jitzu of the Japanese (which I learned from a man who was for eight years chief of police in Nagasaki). The principle of the jiu jitzu is a series of tricks of fence and offence, taught the Samurai, to be employed when by any chance they were deprived of their weapons; and pretty good they are. A friend of mine, a great foot-ball hero in his day, characterized the method as "a series of nasty tricks to do your opponent dirt, which we Anglo-Saxons are taught to regard as unfair." They are not comparable in aggressive power to good boxing, but have their uses, especially as a means of defence for women. Children readily learn them and they serve as excellent training in swift aggressions or defences for a weakling.

In swimming we have a perfect means of training in grace, symmetry and forceful movements. Every child should be taught this most valuable art almost as soon as it can walk.

Boxing may well be taught to little boys and little girls too; if for no other reason than to implant the power of standing firm on the feet under all kinds of difficulty. Curiously enough there is no means of teaching waltzing and guiding in a crush so good as the foot-work in sparring. Since it trains the whole body, including arms, chest and head (especially producing mobility and accuracy in placing the neck) and above all, since it encourages the great moral qualities of patience, good nature and self-restraint, sparring can be ranked among the most valuable of educational exercises.

Of the utility of dancing too much can scarcely be said in praise. It is safe to endorse the unreserved recommendation of a lady whose opinion in all worldly matters commands my respect, who asserts that no child has been properly trained until taught at least the simpler fancy dances, *e. g.*, the sailor's hornpipe and the Spanish fandango. As to "buck-and-wing" dancing, I can only say that it supplies much of value in many excellent directions, but savors of boisterousness overmuch for my taste. The same may be said even more emphatically of jig or clog dancing. Marching, military drill, with or without arms, both offer many valuable opportunities.

The modifications of these as employed by the Turnverein drills, wand and ring drills, "graces," all are to be highly commended when available.

In estimating the utility of any plan of education we should keep always before us the object to be attained. However useful the acquisition of knowledge, rules, principles, etc., may be, most, if not all our daily conduct is regulated by habits. The habitual processes, both mental and physical, become so strong that they dominate not only the individual throughout life, but also nations and races. Habits formed during one epoch impress the citizen maturing in that epoch. Another epoch and different groups of impressions alter points of view. This is peculiarly noticeable in religion as well as in fashions and industries.

Habits are motor modifications in nerve substance, which gradually become stable and accurate through repetition of actions, whereby they grow more easy of performance. Thus is memory made the product of countless actions which have been performed many times before. Hence we remember most easily sense-impressions most frequently received, or acts most often performed. Thus many nerve-paths are developed in brain-cells or fibers, also shorter and easier routes are acquired, through connecting or association structures. Thus habit constitutes organic memory, which may or may not be accompanied by active consciousness. They may be good or bad habits.

It is obvious that this store of working habits, mental and physical automatisms, must be acquired as early and as correctly as possible, so that the essentials of education shall be abundant, varied and precise; and then we may combine and elaborate them as we grow in age and facility. When the time comes to specialize in any direction we have need for an equipment in all the simpler automatisms, that we may group them unhesitatingly to form the basis of our later adaptations.

It is in the last degree unfortunate if our early habits, dynamic associations, are not sufficiently varied and exact to confidently assume precision in responses when we need them as conditions for those specializations which later constitute our life-work.

To attain useful facilities in any line of human endeavor the training of the senses should be systematically pursued from the earliest manifestations of attention. Sense perception opens up the way to form concepts of objects, but is of use only when supplemented by motor impulse. Every normal sense impression tends to pass into movement, and is of use only in so far as it does so; in short, conditions for motor development depend upon sensory impulses.

Mental visualizations, interpretations of images, concepts of form, can arise only through motor outflows. Ideas are of potency in proportion as they include the elements of motion, the impulse to do.

Thought is a word much in use, but the act of thinking is by no means a constant process, even with the most intelligent. Much of what is called thought is, in most instances, merely automatic action aroused by some sensory impulse. To think deeply, to exert intellectual force, is rarely needed in the day's work; but every human being has constant need of myriad accurate automatisms, the product of early and varied associations of sense impressions along with muscular acts. The product of these is the idea, the memory image. When rightly formed, full reactions between observations and applications they become unerring guides to conduct. They serve most of life's purposes and are absolutely essential, are become, in the main, dependable. Promptings must, of course, be incessantly modified by intelligent inhibition, the checking of over-action, judicious selection of courses of action.

Whatever the direction that life-work may take, that child is especially fortunate who is compelled to acquire a store of motor reactions long before the reasons for them are understood. This essential equipment is only to be secured during the period of plasticity, while the tissues, brain-cells, nervous mechanisms, etc., are elastic, impressionable. After this period, which slowly subsides, passing gradually into varying degrees of adaptability, the formation of new yet efficient automatisms becomes increasingly difficult.

THE CASE OF THE COLLEGE PROFESSOR

By Professor WARNER FITE

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ONE of the recognized subjects for public commiseration at the present time is the college professor's salary. Once in so often some disgusted member of the profession writes a letter of protest to his favorite weekly journal and starts a new wave of sympathy. Yet so far it has occurred to none of the complainants to propose, as a serious measure, the policies by which other men have bettered their condition—for example, the policy of organized self-assertion expressed in the trade-union. In the eyes of the profession the bare suggestion is vulgar. The aims of the scholar and teacher, as he will have you know, are essentially disinterested. His work in the world is that of a missionary working for others. Or if the "others" sounds too evangelical, at least his motives are those of professional honor. It is therefore out of the question for him to make any very overt demand for increased compensation. Rather is it the business of society to recognize the delicacy of his position and see that he is properly rewarded.

Yet there is something incongruous in a missionary complaining of his pay. The missionary is supposed to be delighted with hardships and to find ample satisfaction in "the beauty of self-sacrifice." If, like other men, he thinks that he is also entitled to a fair living, then it is not to be seen why the duty should not rest upon him, as upon others, of presenting his account. The college professor may plead in excuse that for him the business of settling accounts is specially troublesome. And it is true that his work calls to a special degree for freedom from distractions, and that to the problems upon which he is engaged questions of compensation are external and immediately irrelevant—while for the business man distractions are the ordinary routine and higgling for higher prices the game in which he delights. Unquestionably, in the interest of the college professor's work, it is desirable that his economic welfare be reasonably secure. Yet if the professor's furnace fire goes out, and no one is at hand to attend to it, he must set about it himself or freeze. By the same token, if society fails to attend properly to his salary, the responsibility rests upon him. And in the end this is the place where the responsibility should rest.

It would make this responsibility clearer if he would frankly ask himself what, after all, he is really standing for. And if the question were once plainly put, he would be compelled at the outset to abandon the illusion of "missionary work." The missionary idea presupposes the poor lad with a keen thirst and capacity for knowledge to whom the college doors are closed. This pathetic image has long ceased to represent any substantial reality. If any such lad is still unprovided for, a hundred college presidents would be delighted to make his acquaintance. As the case stands to-day, it is the colleges who are competing for students and not the students for admission to college. Like the life-insurance companies, the colleges are expending a large part of their energies in securing "new business," and their criterion of progress is the life-insurance criterion of numbers. If the catalogue shows no increase of attendance over last year, the year is counted as lost; and in the matter of attendance everybody counts for one, no matter what kind of a one. "The harvest truly is great, but the laborers are few"—nothing could be further from the truth at present in the field of higher education. So insufficient, in fact, is the supply of ripe fruit that many of the laborers are gathering stalks.

Nothing better measures the active demand for higher education—for *education,* and not for college degrees—than the prevailing academic standards. A few years ago out of a class of forty in formal logic I conditioned ten. A colleague, commenting upon the fact, remarked that "the mortality was rather high"—in which, of course, he was correct. Yet, as I felt called upon to say to the class (many of whom were students of law), if they had been defending themselves by their own logic in a trial for their lives, not half had escaped being hanged. And had they been making shoes, not half the product would have been fit to wear. Think of a factory where the workers receive full wages if sixty per cent. of the product is marketable! Or of a physician who makes a false diagnosis in four cases out of ten! Yet sixty per cent. is the usual academic standard; and, as this standard is commonly interpreted, a student receives credit for the course if he answers correctly six questions out of ten—not *test*-questions, be it noted, but "fair" questions. Similar standards prevail in other matters. Many colleges put up with a laxity of attendance which is unheard of in an office or factory. If it be asked why academic credit should be earned more cheaply than dollars and cents, the answer must be in terms of supply and demand: the supply of student material which would satisfy the standards of fitness that prevail elsewhere is insufficient to meet the colleges' demand for numbers.

In the presence of these conditions, "missionary work" becomes a mere euphemism for academic inflation. And nothing has been more fruitful of corruption in academic life than just this policy of inflation. Nothing has contributed more to lower the college in public esteem or to obscure its purpose as the promoter of serious thinking. In the interest of increasing its numbers every intellectual ideal has been compromised, athletics have been made the determinants of college policy, and college life has become a carnival of "student interests." Nothing, however, has done more to depress the salaries of professors, and at the same time to cheapen the type and character of men considered eligible to the profession. To this, indeed, we owe the preference over the scholar, the student, and the teacher, of the academic *entrepreneur,* or "educator." It is most noteworthy that the Carnegie Foundation, in its search for the obstacles to the advancement of teaching, has landed upon this point first—namely, the cheapening of salaries and of men which comes from reckless expansion. And it is not pleasant to reflect that, while the laboring man is prepared more or less to stand for himself, the function of a trade-union for college professors is left to Mr. Carnegie's foundation; or, further, that the college professor, while eager to share in its benefits, has shown thus far no very hearty sympathy for the purposes of its investigations.

For, in the end, it is the college professor himself who is largely responsible. I doubt if many college men fully realize the intimate connection between the policy of inflation and their own economic position. Most of them are as naïvely enthusiastic over a gain in attendance as a student over a foot-ball victory. And when it is otherwise they are content to lay the burden of responsibility upon the head of "the administration." It is not my intention to absolve the administration; yet there must be few cases where the choice of the administration is not more or less determined by the faculty themselves. In any case, a hostile administration could not long survive a serious and well-considered opposition. As President Schurman says in his last annual report, "A faculty will not be dominated or over-ridden which justly asserts itself." It must always be remembered that, with the exception of the president, the only persons who are with the college all the time, and whose interests are continuously identified with its welfare, are the faculty. And they are the professional experts. Consciously or unconsciously, positively or negatively, they are bound, therefore, to have a large influence upon its policy.

In the matter of inflation they have been more than negatively responsible. Under the opportunities for competition afforded by the elective system, nearly every professor is struggling to magnify the importance of his courses by increasing the attendance. He knows that, under the present conditions, attendance will count for promotion, and further that a large attendance is incompatible with very severe standards; and he finds it easier to conform to the conditions than to raise his voice in protest. Likewise every head of department is striving to make his department the largest, to print the longest list of names upon the department letter-paper, without regard to quality or price. The net result is to strain the financial resources of the institution almost to bursting, and at the same time to lay the foundation for such an increase of fixed charges as to bar all possibility of a more liberal scale of salaries.

In all this the college professor is apt to congratulate himself upon the wisdom of the serpent. The argument of numbers, he will tell you confidentially, is to impress the imagination of legislatures and millionaires, and when a comfortable establishment has been secured, of course all will be changed. But, apart from the fact that the wisdom of the serpent is not the scholar's special brand, and sits not well upon him, if every increase of resources is to be paralleled by a corresponding increase of liabilities, in the form, say, of new departments to maintain, it must be said that the college is playing a losing game. In the meantime there are few, at least of the better institutions, which could not be financially independent on the strength of their present foundation, if only they would have the courage to curtail their product in favor of a better grade of goods. If standards were raised to approximate those used elsewhere, if college education were presented as a privilege, to be reserved for those who will work for it, if the college would determine for itself what it can profitably offer and what the student can profitably take, instead of aiming at a department-store assortment of electives, it would improve its own dignity, increase its real usefulness, and at the same time be able to make a more liberal provision for its faculty.

Inflation of attendance is, however, only part of a general program of extravagance and improvidence. The popular theory of academic finance is the theory of the deficit. Nowhere else is it considered a mark of economic wisdom to spend beyond your income. In the college it is held to be a necessary condition of health and "life." And for the necessities of "life" it is assumed that the Lord will, and will thus be compelled to, provide. At the same time the furnishings of life have acquired a larger importance. It is no longer a matter of Mark Hopkins and a log, but of the log and Mark Hopkins. Remembering that the chief factor in teaching is the personal intelligence of the teacher, it must be said that the salaries of instruction, as compared with the other expenses of maintenance, cut a surprisingly small figure in the budget.

Here again, however, the college professor is largely responsible. Some allowance must be made for the necessary equipment for instruction in science. Yet even here, and perhaps specially here, it is true that too much emphasis is laid on the laboratory and too little upon the man. It is apt to be forgotten that many of the greatest scientific achievements have required only very crude instruments, and that, after all, the aim of science, as of philosophy, is, in the words of Hegel, to be a *thinking* study of things. The fact is that it hardly occurs to the college professor to ask what he can do with the means at his disposal. The same man who, in his household budget, is careful to ask what he can afford, urges the demands of his department upon grounds of absolute necessity. A two-thousand dollar professor will insist unblushingly upon a two-hundred-thousand-dollar laboratory. And by dint of urging and begging he may get it. Of course he thinks that his salary will rise to correspond. He is then much chagrined to discover that what might have been added to his salary is needed for the maintenance of his laboratory; and the responsibility is laid upon "the administration."

All of this goes to show that, in spite of the theory of "missionary work," the activity of the college professor is not a purely altruistic response to a crying need. To this it may be replied that it is precisely in accordance with the missionary idea to endeavor to create the need. All very true, perhaps, but just this may be claimed for every line of business, for jewelry and millinery as well as for preaching. In fact, "missionary work" is one of the stock-features of the slang of advertising. The real question has to do with the nature and significance of the need you are endeavoring to create, whether it be a need for college life and academic degrees or for culture and serious thinking. Whichever it be, it would be profitable for the college professor to recognize that, like men in other trades and professions, what he is endeavoring to create is at any rate a need for himself. In other words, he, like other men, is aiming to develop a field for his own activity. Now he is none the less to be respected for this. Rather do I think, the more. Nor does this lessen the social value of his work. If his work have a genuine intellectual content, it is bound to be worth while, for others as well as for self. The point of criticism is not that the college professor works for himself, but that his self-seeking is so persistently unintelligent; not that his "missionary work" conceals ulterior personal motives, but that these motives are allowed to remain ulterior and to express themselves in ways so ineffectual and so little in accord with the dignity of his profession.

What the college professor needs, then (paradoxical though it seem), is a self-consciousness of his position. He should make it clear to himself that, whatever be the social significance of his aims, he is working at the same time, like other men, for the satisfaction of personal ends, among which is included a satisfactory provision for his living. He should then take upon himself the responsibility of doing openly, deliberately and intelligently what he is now doing covertly and blindly, without cooperation or organization. To this he commits himself by his present attitude. Upon him, then, should rest the responsibility, both of formulating his case and of using the means at his disposal to secure the satisfaction to which he conceives himself to be entitled.

Now when the question of title is raised, he is quite likely to be reminded that his occupation is a rather pleasant one and possesses many features very delightful to a man of scholarly tastes. We need not deny this. In fact, if the college professor is not to lose an important part of his case, it would be well to remember that his demands are not for bread alone. But the beauties of the professorial life are such for the academic man; for the average business man the life would be intolerably dreary. And in this respect, that there is a certain correspondence between work and tastes, the occupation is singularly like many others, and it is not to be seen why the profession of teaching should be specially penalized. It is all very well to talk about "plain living and high thinking." I admit that it is not for the college professor to aim at the pace set by fashionable society. But I can see no virtue in plain living just for itself. Its only value for the scholar is to leave the mind free for high thinking. And if living is too plain, the result may be easily the reverse. Such, in fact, is the present situation. Few college men would be "living high" at twice their present salary. Indeed there are rather few cases where this would constitute more than a properly liberal allowance for the best "performance of function."

But the question as I am endeavoring to state it is not primarily one of abstract justice or social function. It is the more direct question, addressed to the college professor, namely, What are you going to do about it? How are *you* going to make your claims good? As the question is often put, it takes the form of a dilemma: on the one hand, the dignities and privileges of a learned profession, if you will accept a life of poverty; on the other hand, a better chance of a comfortable living, but no opportunity for the things that are specially dear to you. Choose and remain silent, for you may not have both. But most disjunctions are fallacious, and valid only for the stupid. If the college professor is as intelligent as he claims to be he may refuse to accept the choice of alternatives and assert his intention of securing for himself both a liberal living and the opportunity for an intellectual life. And he will do so, as I have suggested, by applying to his own case the principle of organized self-assertion which is illustrated in the trade-union.

The mere suggestion is too much. Imagine, if you please, a strike of the college faculty for an eight-hour week, a cordon of police about the university, the professor of education, as walking-delegate, puffing a black cigar into the president's face, while "scab" instructors, supporting a family on a thousand a year, are teaching depleted classes in fear of their lives! Yes, but why imagine all this? I am speaking presumably of the self-assertion of intelligent men, of men, indeed, who claim to embody the highest intelligence of the community. And

I am standing, not for trade-union methods, but only for the trade-union principle, namely, the principle of self-assertion. If your college professor can assert himself in no better style than the labor-union, his intelligence is an illusion and he has no case. The working man can conceive of no way of bettering himself except at his employer's expense. In his view there is a fixed margin of profit between a fixed cost of production and a fixed market-price, and what is added to wages must be deducted from profits. And having no personal authority, by virtue of education or social position, he can conceive of no way of asserting his claims without the exercise of economic pressure or physical force. It should be the aim of the college professor to prove, in ways already suggested, that he may indefinitely better his position, not at the expense of his college, but in the very process of making it a more worthy and influential institution; and that for this the chiefly potent force will be the authority of his position and of the argument that he is able to present.

But for this purpose it will be unnecessary to form a special organization. For the college professor is already organized. Practically every member of the profession is a member of a college faculty and also of one or more learned societies. The latter, of course, as associations of men united by the interests of a special line of work, bear a nearer resemblance to the trade-union; and they would not be going out of their way if they should include the advancement of the scholar in the advancement of learning. But for our immediate purpose the college faculty is more important. For as a member of the faculty the college professor already holds a franchise of considerable possibilities, and a place where he is authorized to speak, where, indeed, he is responsible for expressing himself regarding the welfare of his college, and where, as I think, he may also rightfully represent his own claims and those of his order. Simply to make a responsible use of his official prerogative would go far toward improving his position. And if the college professor is ever to assert himself, this is the place to begin.

For this in fact is the point at which he is most conspicuously weak. Nowhere does he appear to less advantage than as a member of the faculty in faculty-meeting. It may be doubted whether any other assembly of men indulges in more ill-considered talk and more ill-considered action than the average faculty. Men who habitually talk sense seem here to talk nonsense. They advance confident opinions on matters that they have never considered; on the spur of the moment they offer motions, often of a far-reaching import, whose meaning they are afterwards unable to explain; they entrust special business to committees and then ignore the committee-reports; and they constantly illustrate the law of action and reaction by reversing at the next meeting the measures of the last. The fact is that the individual college professor, however responsible in study or class-room, has as a rule little sense of the dignity and responsibility of his office as a member of the faculty. And it is also true that many men are admitted to our faculties who, by reason of inexperience and immaturity, or of constitutional lack of culture and self-respect, should not be entrusted with the office. Nothing better demonstrates this than the fact that measures pass to which a large majority are heartily and sincerely opposed —measures which, it may be, are clearly to their disadvantage. Let it be known, however, that the measure is the president's own, there will be few to vote against it, almost none to speak against it. The majority conceal their want of frank courage under a Pickwickian conception of "loyalty."

Thus it has come about that the seat of authority in college matters has passed to a large extent from the faculty to the president, who, then, by analogy with commercial ideals—to which college men are often curiously deferential—has been invested with the character of captain of industry. Now the captain of industry may be necessary in the business world, where, perhaps, most men are fit only to be led. And I do not doubt that the modern college will need an executive head, whatever be his relations, on the one hand to the trustees, and to the faculty on the other. But that the college professor should himself adopt the *entrepreneur*-theory of the office, as he frequently does, and should even glorify "the rule of the strong man"—over himself, can stand only for an utter contradiction between the idea of his profession and its present actuality. In a word, it is an incredible attitude in one who believes himself to be a scholar and a gentleman and who attaches any moral significance to the fact. If the democratic principle is to hold anywhere, it should hold here. But it can hold nowhere unless men have the courage to say what they mean and a responsible meaning to express.

Accordingly, as the first feature in the program of self-assertion, the college professor should seek both to strengthen his authority as a member of the faculty, and as such to secure for himself a more comprehensive representation in the government of his university. In this, while cooperating with the president and the trustees for the welfare of the institution, he will at the same time act with an explicit reference to his own. There is no reason why the attitude of any of the parties to the situation should be purely impersonal. The welfare of a university is represented in the fulfilment of the numerous interests which it may be conceived to represent, and these interests are in last analysis personal. The aim of college policy is their coordination, and in the college especially, a broad computation of each should leave little margin for dispute. But if all computations are to be impersonal there will be few suggestions of value to interchange and few data either for the problem or its solution. And if the college professor is to be represented anywhere, it should be by himself.

Hence, there need be nothing in faculty representation which is invidious to the rights of either president or trustees. And there is reason to believe that responsible representation would in many cases be welcomed. To quote again from President Schurman's last report, "No greater good could come to Cornell University than a quickening and deepening of the faculty sense of responsibility for its welfare. Too often the faculties of American universities have rolled all responsibility on the president and trustees." And later he adds, speaking of the relations of the faculty to the executive officers, "It is for them [the faculty] to keep the institution democratic. And nowhere else is democracy so important as in the university."

Then, secondly, as embodying the point in which he is most directly interested, it should be the aim of the college professor to have all academic appointments made publicly, with sufficient time allowed, if possible, to secure the consideration of all available candidates; and to have the list of candidates submitted for consideration to a committee of the faculty, chosen by the faculty themselves; and further to include in this policy the matter of salaries and promotions. I know that at this point gentlemen will cry, Politics! Politics! But it must be remembered that politics open and aboveboard is no longer "politics." There can be no "politics" except where there is secrecy, as under the present system of pocket-appointments.

Thirdly, however, it should be his aim to have the general features of the budget submitted for consideration to a similar committee of the faculty. At present the budget is supposed to lie wholly beyond the faculty's domain. Yet there are few questions in which it is not more or less involved, from the granting of a scholarship to a new system of electives. In the college, as elsewhere, it is a question always of what you can afford. And what you can afford is a question of the various alternatives. If the faculty are to act wisely, either for themselves or the college, they must know the financial possibilities. And if the trustees are to spend wisely, the recommendations upon which they act must have had these in mind. Under the present system of non-communication expenditure is too often footless. And nothing has done more to discourage the faculty sense of responsibility than the feeling that only part of the situation is shown them and that the president holds a card up his sleeve.

Finally, in the interest, both of himself and his profession, he should insist upon a high standard, both of scholarly attainment and of personal culture and responsibility, for academic appointment; and especially should he insist that membership in the official faculty be restricted to men of rank and maturity. In other words, like the laboring man, he should seek to protect himself from irresponsible competition. And if he is to stand for himself, he must stand for this above every thing else. For in the end the force upon which the college professor must chiefly rely is the authority of his character and his profession.

The program thus outlined would imply an eventual readjustment of constitutional rights. But it need not wait for this. The main point is that the college professor should undertake to speak in matters of college policy, both for himself and for the college, and that he should then secure consideration of what he has to say. If this is accomplished, he can afford to wait for recognition by law. For, after all, nothing is so potent as a reason, if only it can get itself considered. And none should be able to offer a better reason than just the college professor. His reason once formally made public, few presidents or boards of trustees would care to turn him down without a very good reason in reply. One of the sharpest contests in the history of college politics was over the question of a veto. The president had an unlimited power of veto over the action of the faculty—could he ask more? Yes, a little more; he might disregard the faculty's vote without committing himself to a veto. And this was the sole point in dispute. What it meant was that the president cared not to appear before the university and the public with his faculty's support withdrawn.

The program of self-assertion imposes upon the college professor a considerable increase of responsibility. If he is to be responsible for himself he must also assume a responsibility for his college. And to responsibility he is commonly adverse. But upon him the matter rests; and if he declines, he should forever keep silent about the narrowness of his conditions.

THE CONSULTING PSYCHOLOGIST

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TO the popular mind the "consulting psychologist" is a medium in the rookery on Broadway to whom one may go for paid advice—decidedly practical. But the meaning ascribed to the term by Professor Royce, in his now classic address before the National Educational Association, twelve years ago, has perhaps found some recognition. It is in this sense that I shall use the term.

With the growth of science comes the specialist, and with the development of the specialist comes the consulting specialist—a man who does not engage in competition with the rank and file of the profession, but conserves his energies and fits himself for dealing with special problems. In the past the consulting practise has generally come as a result of preeminent success in ordinary practise, and from a desire to select the most important work. This is illustrated in medicine and engineering. But with the passing of the self-made man, and with the growing differentiation of work, comes an opportunity for the trained specialist, still young, to get recognition for special service. In all the branches of medicine and engineering, and in many other fields, there is now a demand for the man who is master of something specific. Now, as psychology becomes a science and so begins to show signs of being of practical value, there is more and more demand for men who have not only a thorough mastery of the subject, but who will devote themselves to some aspect of its application.

We are just now at an epochal turning point in psychology. The subject is passing its infancy as a pure science and the world has taken us all too seriously in the promise of what we can do to be useful. We stand amazed in the face of the confident and insistent demand from the various walks of life for psychological principles of explanation, organization, guidance, economy, efficiency, conservation, expansion, growth, evolution, development, transference, impression, retention, elaboration, attention, affection, action, fatigue, rest, etc. The demand comes from the arts, the sciences, the professions and the industries, as well as from the patrons of liberal culture. Education as a science knows no other foundation equal to psychology; fine art, in all its branches, is interpreted in terms of psychology; social, charitable and corrective agencies grope for psychological justification in every movement; medicine, as it faces the bewildering ills of mental life, recognizes the necessity of a psychological point of view and technique; law has caught a glimpse of the fact that it has to deal with human nature; the ministry has hit upon the fact that the soul which is to be saved and made like unto the divine is the human mind; the merchant has discovered that impression, attention, interest, satisfaction and action in salesmanship can be enhanced by knowledge of the laws of human nature; the manufacturer is beginning to realize that skill, invention, economy of process, etc., can be improved by knowledge of the nature and laws of the psychophysic organism; the great wave of interest in the conservation movement which is sweeping over this country reveals the fact that the most serious depredations we have to check are the inroads upon the human mind, and the most precious resource which the country has to conserve is the mental energy of the race; preventive medicine and eugenics invoke the science of the mind to decrease ills and increase power, happiness and beauty of mind.

In short there is a very great demand for applied psychology. The world believes in it. What, then, shall be our attitude toward this demand? I venture to suggest a point of view in the following four propositions:

1. The facts of psychology are fast becoming common knowledge which will profoundly influence thought and action. Men in all walks of life will apply their knowledge of mental life; but, be they ever so well grounded in this science, psychology is not their calling, and they will treat it merely as one of many points of view in their broad outlook.

2. All psychology is more or less practical. The psychology of the class-room is not a mere decorative frill, and we are not all the time tuning our fiddles in the academic laboratory; but the primary aim and ambition in all is academical, and it should be.

3. Research in pure science is farsighted, and thus ultimately of the greatest service. The work must be fundamental. This is its chief merit and distinguishing trait. If the investigator who gave Marconi the principles of wireless telegraphy had aimed directly at the saving of ships at sea, he would probably have failed; but he devoted himself to the mastery of an abstract principle and laid a large foundation. Countless achievements may be built upon this foundation.

4. There remains a distinct field for the consulting psychologist, an expert in psychology who may be employed as adviser in matters pertaining to the ascertained facts of mental life with reference to their bearing upon a given practical situation, or may be employed to search for or verify such facts by special investigation. He is the Marconi of psychology; the man who works out the application.

For convenience we may divide the field open to the consulting psychologist into four large divisions, namely, (1) mental pathology,

(2) education, (3) technical arts, crafts and professions, and (4) eugenics. This classification is not all-inclusive nor are the divisions mutually exclusive, but some such divisions may be helpful in blazing the trail.

The first division embraces all institutions for those who deviate from the normal condition of mind; such as insane asylums, schools for the sensory defective, institutions for moral delinquents, homes for the feeble-minded, epileptic colonies, the provision for the abnormally retarded and mentally defective in the public schools, and special schools, clinics, foundations, laboratories or retreats for the study and treatment of mental deviation. As the physician is at present more in demand for the curing of disease than for preventive measures, so the psychologist's first mission will be to the mentally suffering. The alienist will share his duties with the consulting psychologist; the superintendent of the charitable institutions will be guided by his advice to a large extent in organization and management of institutions; the segregation of mentally defective pupils in the public schools will be under his supervision; and, in the special institutions for the investigation of mental troubles the psychologist will, of course, be the central figure.

The second division embraces the vast field of applied psychology in the organization and administration of the education of normal individuals. This does not refer to the work of the professor of educational psychology, nor to the psychologically trained superintendents, principals or teachers, but to the experts who are available for consultation work only. The consulting psychologist will be found in the research laboratory of educational psychology, in the research laboratory of other educational agencies, in the office of the city board of education (or in the superintendent's office), in the office of the state superintendent of public instruction, and in the national bureau of education. We have recently heard the assertion that the railroads of a certain section of the country could save a million dollars a day by scientific management; but it would be less hazardous to say that the patrons of the public school system of the country could save a million dollars a day by the introduction of psychologically scientific management of instruction. The principle is the same, and the one measure is as tangible as the other; neither has been solved and neither is the task of a day; both are progressive measures. The first thing essential is that the administration shall have faith in the aim and effort of the expert; and second, that the expert shall be willing and able to make good. Both are in sight. If the money now paid to authors of children's first books in reading were paid to a group of experts for a dozen years some fundamental principles of mental economy in learning to read might be worked out so as to be of permanent guiding value to authors and teachers of primary reading. As it is, the psychologist who to-day is the greatest authority on the psychology of reading, and who has done more on the subject than any one before him, has merely nibbled at the subject for spare moments, in the midst of an otherwise busy career. One such man alone devoting himself to the subject for a lifetime with suitable facilities at command could accomplish wonders. Or, take the subject of arithmetic. Would it not be good economy for the national bureau of education to employ a dozen experts for a dozen years with adequate facilities for experiment and consultation to work out some principles which should determine the elemental contents and fundamental methods of a child's first book in arithmetic? The absence of such principles is notorious. As the promoters of the automobile, the flying machine and countless other enterprises are now watching the work of the electrical chemist in his struggle to invent a new battery for the storing of electrical energy, so the eyes of the educational world will be upon the man who goes into his laboratory, surrounded by all the aids his science can furnish, in systematic search for ways of conserving the mental energy of the young in school so that a new order of things educational may become possible. A young man of marked ability having to choose to-day between the plan of devoting his life to the intensive study of one practical psychological problem, on the one hand, or the academic career as a teacher, on the other, may well choose the former as the more promising of permanent contributions to science for the good of mankind. As the well-qualified men appear, positions will be created for them providing for their bread and butter.

The third division embraces a great variety of situations in which the consulting psychologist may be employed in determining courses of action, principles of efficiency, principles of economy, principles of validity, etc. Thus in manufacture, there is constant waste of human energy for want of knowledge of underlying mental laws which might be applied for the improvement of the type of mental activity involved; *e. g.*, for shortening or simplifying movements, for facilitating perception and discrimination, for enhancing appreciation, and for increasing the effective output of energy. The lawyer has abundant opportunity for seeking expert information in regard to the laws of human nature. In medicine the present movement in psycho-analysis is an illustration of the opportunity for detailing a trained psychologist to work out the case by technical methods which require much specialized skill. Advertising which now employs very high-grade writers and illustrators appeals to psychology for fundamental principles in regard to the work of attention, feeling, satisfaction, convincing argument, etc.

The fourth field really belongs to a future generation, for, although we are seeing it full of promise, eugenics, the welfare of mankind, is to us as yet quite unfathomed. The improvement of the race, direction in the choice and preparation for a vocation, social adjustment, the scientific reduction of crime, and the increase in the sources of human happiness—these are all possible, but distant goals of applied science.

To illustrate more specifically the work of the consulting psychologist in one type of situation, we may take the first field of the four just outlined, namely, mental pathology, bearing in mind that the functions may vary greatly with differences in men, institutions, times, etc.

The consulting psychologist in institutions for mental ills has two fundamental types of function; one that of advice, and the other that of research. Both are necessary for encouragement and growth of the man himself and for the good of the institution. In the capacity of adviser, he may be expected to place at the disposal of his superior officers the latest gleaned and verified facts and theories on the issue in hand and to lend such aid in their adaptation and introduction into the routine of the institution as circumstances may permit; and in the capacity of investigator he may direct, or personally conduct, research for the solution of pending problems. Thrown into tabular form his duties and privileges of advice and research might be listed as follows:

I. *Advisory.*

1. Testing, classifying and sorting cases on admission.
2. Planning and utilizing the case history.
3. Systematic observation and experimenting on the progress of each case.
4. Adapting treatment, training and adjustment.
5. Technical instruction to the staff.
6. Education of the public (information in regard to preventive measures).

II. *Research.*

1. Original experiments on the value of new types of treatment, training and adjustment.
2. Intensive study of individual cases.
3. Search for needed psychological facts by scientific experiments.

Thus, on the advisory side, he aids the superintendent, the staff and the public by making known and adapting applied psychological principles; and, on the side of research, he tests results of procedure in scientific terms, is ever alert for the discovery of instructive cases which may come under his observation, and directs psychological research for immediate practical purposes.

Perhaps the nature and scope of the work of the consulting psychologist in this illustration from mental pathology may be further specified by pointing out some limitations in a negative way.

The consulting psychologist is not a general administrative officer. There is, perhaps, no better training for a superintendency or other executive work in this type of institution than psychology; but, as in business, if the stenographer becomes president, he gets another stenographer; so here, if the consulting psychologist goes into executive work, let him get another consulting psychologist; for, even if the superintendent be the best trained for expert work, his duties are of a general administrative sort and he can not afford to devote himself to the details of technical work. And if the psychologist is to be successful in the long run, it is desirable that his ideas shall pass muster in the superintendent's office before they are put into operation in the routine of the institution. The temptation to undertake executive duties and to infringe upon the rights of the executive is a natural stumbling block, for it is human nature to reach out for power especially when there seems to be a crying need for its exercise. The consulting psychologist has come about as a result of the differentiation of function and he will find himself permanently only as he recognizes that he is a specialist and limits himself to the work of advice and research within a narrowly limited field, respects the dignity of his calling, and covets no other.

The consulting psychologist will not dissipate his energies in general psychology. While a broad training in theoretical and experimental psychology is the best asset with which to start the career, his success as an expert will depend largely upon his willingness to steer clear of pure science problems and his determination to devote his ingenuity and best energies to the adaptation and application of facts already known. There is a constant temptation to evade tasks of achieving something practical for the pleasure of browsing in the green pastures of all knowledge. Like Edison he must stick to his beakers and batteries even at the expense of public ridicule.

The consulting psychologist does not yield unduly to pressure for results. One of his chief duties is to forestall the precipitous rush into extensive application of what may be at best but a specious principle. He will dare to say, "I don't know," even if it should take him years to search for the seemingly trifling fact. While we but little dream of the possibilities in command of applied psychology, there is in the present atmosphere entirely too sanguine a feeling in regard to what it can do on short notice. Instead of being hazardous at guessing, the consulting psychologist must have courage to demand that he have the privilege of making patient search before he prescribes. Thus he has to pass through the narrows with the danger of dissipating his energies in aimless search for truth for truth's sake, on the one hand, and, on the other, the danger of hasty and ill-advised rush into practise.

The consulting psychologist is not a reformer. People think that he holds the magic wand and can transform situations suddenly. If inexperienced, he is likely to enter upon a program of reconstruction, for all seems wrong; but, as soon as responsibility is placed upon him for the consistent readjustment of one particular little feature, he will tone down, haul in his flying colors, and investigate the ground on which he stands. He may even go so far as to feel that whatever is is best under the circumstances. Here is where his mellowness of experience, knowledge of men and evolution of institutions, and his practical sagacity will be tested. If he is shrewd he will progress slowly and by such steps that both he himself and his superiors may acquire confidence in his work. At the same time he will miss no opportunity of making himself useful in a tentative and provisional way.

He is not a practising physician. While a medical education is most desirable he must have a really different point of view from that of the practising physician. In the first place, he observes and recognizes the mental half of man in a way in which the institutional physician does not; and herein lies his mission. His place is to supplement the work of the physician.

He does not surrender his scientific freedom. With all these restrictions he must demand one great privilege, the freedom of a man of science. Unless he is given time for patient and deliberate search, freedom from necessity to rush into print, exemption from excessive routine duties, reasonable physical equipment and assistance, he can not grow into that scholarly attitude which is necessary for effective work and results on a large scale.

What then shall be his training? Applied psychology is more difficult than pure psychology, if such there be. The consulting psychologist must, therefore, like all consulting experts, come with high qualifications. In the first place he should have the laboratory training in psychology which would correspond to that required for the doctorate in order to get thoroughly impregnated with the spirit of research, but this graduate work could profitably be planned with reference to the field he is to enter. Then he must have knowledge of, and training in, that phase of work which he is to pursue, such as education, medicine, sociology, etc. And in addition to this academic training he must go through a process of apprenticeship in the field before he is qualified for the most responsible work. But he will be a university product in the best sense, and the universities must rise to the recognition of this opportunity for usefulness.

Just one concrete illustration of what a consulting psychologist is doing now in the way of scientific adjustment in an institution. In the New Jersey Training School for Feeble-minded, at Vineland, Dr. Goddard, in most hearty cooperation with Superintendent Johnstone, has carefully graded the children by the Binet method; *i. e.*, he has determined the age of mental development and capacity, as opposed to the physical age. The children are then kept under systematic observation by the staff and record is made for the purpose of establishing norms indicative of what the children of each mental age are capable of doing. Each individual is then assigned daily lessons and duties according to the norm for his mental age. The work has not yet been carried far enough to fix final norms, but the very introduction of the principle of seeking such adaptation has had a most wonderful effect on the institution. Thus, a boy who has had eighteen birthdays and is of normal size enters the institution as a helpless dependent; he is tested under the direction of the psychologist and is found to be mentally of the calibre of an eight-year-old and is therefore classified with the group of that age. The norm shows that a lad of eighteen but mentally developed only to the age of eight, and with slight, if any, prospects for further development, can not read, nor write nor figure serviceably, but he can feed himself, make his bed, fold his napkin, keep himself clean, help a crippled brother, lead a horse, carry water, pitch hay, hoe the garden, toss a ball, do small errands, etc. (the items specified are fictitious). He cares little for play, but is an automaton, glad and effective in repeating the same simple tasks. His program for each day is therefore mapped out according to the norm showing the upper limit of what he can do. The result is that he is busy all day, industrious and useful and therefore happy and good. The secret of it all is that he has *found his level* and *is allowed to live on it.* His ambition is realized and he is proud and grateful for what he can do. He is an illustration of scientific adjustment. Compare this boy with his equal in the ordinary institution for the feeble-minded where he is detained as an inmate out of adjustment, irritated by the things he can not do. Adjustment transforms an institution of detention into a house of happiness and usefulness; and, instead of being expensive, it makes the institution more nearly self-supporting, for every individual is assigned to the place of his greatest efficiency.

In conclusion, let me sum up this all too brief appeal. Applied psychology can not always live by the crumbs that fall from the professor's table, nor can it get its full vitality from the non-psychological professions. It must be fostered by the specialist who devotes himself to it for its own sake. It must recognize itself, its own peculiar technique, its vastly varied fields, its diversities, its stupendous difficulties, its essential limitations, and withal its promise and worth.

THE WORK OF THE CHEMIST IN CONSERVATION[1]

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AMONG business firms it is the custom at regular intervals to stop and take an inventory of the stock on hand, to set opposite one another the income and expenses of the past, and to strike a balance which shall show the condition of the institution. Within the past few years this country has been engaged in such a stock-taking of its natural resources and we have reports from various quarters as to its condition, showing that its affairs, in respect to these resources, have been recklessly managed and that without a change in its methods it is rapidly traveling toward insolvency.

We learn that the end of our mineral deposits is in sight; that the United States produces every five years as much iron as the whole world in the 350 years previous to 1850; that in 1907 over 100 times as much steel was made as in 1874; that our coal, which was millions of years in formation, is being dissipated in hundreds, and even in tens. We are told that the next generation may see the end of our anthracite coal and that, while the bituminous may last ten times as long, the limit of the amount available can be closely calculated.

Recent developments in the use of petroleum as a fuel have been rapid. This is also true of its derivative, gasoline, which, up to the present time, is the only satisfactory fuel to furnish energy for aviation and one of the most successful in boats, automobile motors and for many other purposes. Such an enormous demand has been created that the United States Geological Survey predicts that the known supplies of petroleum can not last more than about fifty years. The closely related natural gas is being used at an alarming rate and no scientist claims that its production approaches the rate of its consumption. Charcoal as a source of heat is practically negligible. Our forests are disappearing—half a million acres annually for railroad ties; fifteen acres for a single issue of a metropolitan newspaper; an estimated total consumption of wood amounting to one hundred thousand million board feet.

This depletion of our resources is perhaps a necessary accompaniment to the demands of an increasing national prosperity; but the case has an even darker side. The waste of material is terrific. The Anthracite Coal Waste Commission reported in 1893 that "for every ton pro-

[1] An address delivered to the Society of Sigma Xi, State University of Iowa.

duced one and one half tons were lost." That is due to our carelessness: to our limited knowledge is due the waste of over ninety per cent. of the energy of the coal burned under our steam boilers but not given out by the connected engine.

In the preparation of blast-furnace coke from coal by far the greater part of the by-products are not saved. Thus Bogart states that in 1907 62,000,000 tons of coal were coked, but only 14 per cent. in such a way as to recover the by-products; that by this process there were wasted 148 billion cubic feet of gas worth 22 million dollars, 450,000 tons of ammonium sulphate of as great value and tar to the value of nine million dollars, and that the gases lost annually in the coke industry have a calorific power equal to four billion kilowatts, or three billion horse power. As to natural gas, the United States Geological Survey accepts the judgment of State Geologist White, of West Virginia, that not less than one billion feet are wasted daily. "This," he says, "equals the annual consumption of natural gas reported for 1907. This waste should furnish light for half the urban population of the United States."

Of our forests thousands of acres are destroyed each year by fire and, in addition, a large part of the cut is left to rot as stumps, tops and branches, only the best part of the trees being used. The story of the soil has been similar; we have raised crop after crop from it, robbing it of the elements which the plant must have for the building of its tissues. Of all except three of these the average soil has a sufficiency, but potassium, phosphoric acid and combined nitrogen are frequently deficient. Inasmuch as plants can not thrive unless all their needs are provided for, it follows that these must be supplied if they are in any degree lacking. At present we are drawing heavily upon our resources of all three. Potassium, in early days derived from wood ashes, is now being taken from the immense deposits at Stassfurt; but it is a well-known fact that recently the German government has taken measures to largely prevent the exportation of their output. Phosphoric acid has been furnished by our mineral phosphates, which have been recklessly drawn upon for domestic use as well as for exportation until the supply is sadly impaired.

Some species of plants can utilize the free nitrogen of the atmosphere, but most of them can assimilate this necessary element only when it has been previously combined with others in such compounds as saltpeter, ammonium salts or organic matters. One of these, Peruvian guano, has already disappeared. The great deposits of sodium nitrate —Chile saltpeter—on the west coast of South America are being fast removed. Nearly one hundred million dollars' worth are shipped in a year and thirty to forty years will probably see the last of this supply. No other known deposits can replace it. The ammonium salts from our gas-works are totally inadequate to the demand. These are but typical wastes.

Our improvidence is shown in other fields. Our average mortality is high, exceptionally so among infants. Take an example near home. In the month of July last 245 infants under one year of age died in the state of Iowa, 109 of cholera infantum. Last August there were in the same state 1,785 deaths: of these 472 (more than one fourth) were under 5 years of age; of these 350 (about one fifth of the total) were under one year. Of the infants 291 died of cholera infantum, a disease difficult to cure but nevertheless recognized by sanitarians as entirely preventable. Illness is frequent in the whole country. According to the Report of the Committee of One Hundred on National Vitality, three million people in the United States are at all times seriously ill, half a million of tuberculosis. Drugs and stimulants are used excessively; food, improper in quantity, or in the kind and proportions of its nutrients, is often the rule, thus lowering human vitality and decreasing efficiency.

The food and water that we eat and drink, the atmosphere that we breathe, are deteriorating. The mere mention of food adulterations will suffice. Our industrial waste products are poured into our streams; our sewage and garbage, for the most part, directly or indirectly, share the same fate. The quality of our inland waters is therefore steadily deteriorating. We can depend less and less upon our rivers, springs and shallow wells for domestic and city water supplies. Even the industries where a pure or an impure water represents the difference between a high grade and an unsatisfactory product, are seriously hampered by being limited to a badly polluted water for steam making and other purposes. Many of our fresh-water fishes have become locally exterminated, particularly in the eastern manufacturing sections, and many a smiling river, and pleasant stream, have become converted into mere open sewers which carry away, more or less efficiently, unidentifiable contaminations.

The pollution of the atmosphere has increased with civilization. Not only are the gases from our heating and power plants blown into the air with half-consumed matters in the shape of soot and cinders, but from chemical industries acid gases and other noxious products are allowed to escape and to drift whither they will. The sulphur dioxide from the smelters destroys vegetation, including forests, for miles around. When these are gone denudation commences and rapidly progresses until the region appears a veritable desert. Arsenious oxide is usually found in such gases, and not only aids in the destruction of the vegetable world, but, over great areas, leaves the marks of acute or chronic poisoning upon the animals that graze within the district and upon human beings that breathe the air. In comparison with these effects the pecuniary loss from materials lost in smelter smoke may seem unimportant, but measured in dollars and cents it is considerable. Take, for example, bismuth for which there is a steady commercial demand. According to a conservative estimate, in the smoke of the great Washoe smelter at Anaconda there are lost 880 pounds daily. Considering that 10,000 pounds represents the annual American production, it is evident that eleven days would see a waste equal to a year's output of our mines.

Such is the black picture that is painted for us. What of the future? Must the human race abandon a large part of the earth's surface, which it has conquered, because of insufficient means to maintain its bodily warmth? Or must it become a race of troglodytes, dragging out its degenerate existence in the caverns of the earth? Will our agriculture deteriorate, little by little, until the scanty crops from an impoverished soil hardly support a degraded people? Or will the air and water become so polluted that the race, if it be not so modified as to meet the new conditions, must become extinct? Is our boasted civilization only a myth, the growth of which leads inevitably to destruction?

Can our natural resources be so conserved as to supply the immediate and the future needs of the nation? Of what avail is our science which we have so often exalted, and how far can it help us in the solution of this perplexing problem?

We must see that the only conservation which can avail is conservation with utilization, a concept which was clearly set forth by President Taft in his recent St. Paul address:

> The idea should not be allowed to prevail that conservation is the tying up of the natural resources of the government or indefinite withholding from use. Real conservation involves wise, non-wasteful use in the present generation, with every possible means of preservation for succeeding generations.

As we face the problem can we say, as did Patrick Henry, of political questions, "I know of no way of judging of the present but by the past," and, judging by the past, has our science achieved anything which should give us unshakable confidence in its power to meet this crisis? Let us look back into the not too distant past of science for the answer. It comes from many parts of her realm. I may perhaps be pardoned if I draw most of my illustrations from that field with which I am most familiar.

While science has met the demands of the time as they have arisen she does not, as a rule, much anticipate them. It was only after years of extensive working of the saltpeter deposits of South America that in 1889 Sir William Crookes brought home to the civilized world the true significance of the situation—that the supply of combined nitrogen was approaching exhaustion; that this meant the cessation of plant and animal life, and that to avert such a calamity new sources of these compounds must be sought. At the time one means of relief was suggested by him—the fixation of atmospheric nitrogen, that is, the conversion of this gas, inert and non-utilizable, into nitrogen compounds which could be assimilated by the plant and from this pass to the animal for the building and repair of its tissues. There was the problem for the chemical engineer and the chemical engineer has worked out its solution. The principle employed is to burn the nitrogen of the atmosphere through the agency of the oxygen, by passing the air through a flaming electric discharge. Although this sounds simple, the commercial operation was most complex. The shape and size of the electrodes and their container, the correlation of quantity and intensity of the electric current, of the temperature and volume of air, all demanded patient care as well as expert knowledge. Not only must oxidation be controllable, but the costs must be studied and reduced until a commercial success was assured. The first companies did not succeed and went into bankruptcy, but now, using the power of the mountain streams of Norway and the Tyrol, the nitrogen of the air yields its freedom and leaves the factory as calcium nitrate and sodium nitrate, which go to be mixed with the other constituents of artificial plant foods, or as nitric acid, which is used in so many technical processes. There are now in operation chemical plants which can place upon the world's markets annually 100,000 tons of pure calcium nitrate thus obtained through the use of atmospheric nitrogen.

While one group of chemists were following this solution of the nitrogen problem others had taken another line, influenced partly by a different motive. This was the development and an outgrowth of the calcium carbide industry. After the French chemist, Moissan's, brilliant work upon the production of carbides by the electric furnace the field was occupied commercially and in many places where cheap water-power could be obtained—Niagara Falls, Norway, Switzerland and others—calcium carbide was made for acetylene lighting. The annual output is about 200,000 tons. But this is more than is called for in the preparation of acetylene. There must be some way of using the excess, and the services of the chemist were in demand.

When free nitrogen is led over calcium carbide at the proper temperature it is absorbed, forming calcium cyanamide. The latter is decomposable by steam, its nitrogen being evolved as ammonia, a valuable plant food. There is the same decomposition when the calcium cyanamide is placed in the ground; the decomposition is then so slow that the ammonia does not escape into the air, but is held in the soil until it is utilized by the plant.

Thus the chemist has built another bridge over the gulf between free and combined nitrogen, cyanamide, or "nitrolime," acting as the middle pier. Nearly 200,000 tons can be annually furnished by the works now built or under construction.

Thus chemists and chemical engineers have answered the demand of the hour. With the boundless atmospheric nitrogen and with water power, the development of which has scarcely begun, man need never fear an insufficient nitrogenous food supply.

We are inclined to lament because of the extent to which some of our limited natural resources, such as iron, are being drawn upon. But if we compare the condition of the people of the United States now with that at the time when these resources were comparatively untouched we must admit that their use has added immensely to human comfort and progress, and that this increased comfort could have been gained in no other manner. In addition we must consider that, although much material is being used, the processes of putting it upon the market are gaining immensely in economy of operation through the studies of scientific men, and that much that we were in the habit of discarding is now used repeatedly. So that the total amounts taken from their terrestrial storehouses does not fairly represent the loss to humanity.

For instance, since the time of Tubal Cain until about the end of the fifteenth century iron ores were reduced in a crude forge where the yield ran from 100 to 300 pounds per charge—far less than a ton per day. Compare the continuous process of the modern blast-furnace producing 75,000 or more tons annually and think how many conveniences we should be deprived of if we were still limited to the primitive methods. Compare also the price per ton of pig iron from the old and the present processes and no doubt will remain that wastefulness is relatively immensely less in the iron industry now than then. Nor is iron once used discarded, but it is worked over into new forms and employed for other purposes.

Previous to 1856 the only means of producing steel was to laboriously remove the carbon from the pig iron in the puddling furnace, roll the iron into bars, slowly add the requisite carbon again by heating the two together for days, and melting or hammering to get a homogeneous product. But in 1856 Henry Bessemer announced his process for making steel from pig iron in one operation, a process so simple that we please ourselves by thinking that we might have invented it if it had not previously been done. Bessemer found it necessary only to burn out from the molten crude iron the impurities, carbon and silicon, by a blast of air forced into the bottom of his crucible, just as we stimulate the burning of fuel in our fireplaces by the use of a bellows. No fuel was added as the heat from the burning impurities was adequate to keep the mass melted until the change was complete. To the purified iron thus obtained he added the requisite amount of carbon and, in half an hour, had a dozen tons of steel. The price of steel rails before and after the Bessemer process came into vogue is a testimony not only to the knowledge of the metallurgist, but to the saving in time, labor and fuel, a real conservation of resources. More recently as high grade ores suitable for the Bessemer process are becoming scarcer the metallurgist has added to his equipment the open-hearth furnace in which ores of a much inferior quality can be smelted.

The history of aluminum offers an even more striking illustration. For many years after it was isolated by Wöhler from its fused halogen compounds through the addition of metallic potassium it was somewhat of a chemical curiosity. Owing to the high cost of potassium the lowest price at which it could be sold was several dollars an ounce. It could not be bought in any large quantity. I distinctly remember the pride with which one of my earliest teachers of chemistry was wont to exhibit to his classes a piece of aluminum about as large as his finger, and with what delight he would tell of Wöhler's custom, in saying good-bye to his newly made doctors of philosophy, of bestowing upon those with whom he was particularly pleased a piece of the precious metal, this being such a fragment. That was not many years ago; yet in 1907 there were produced in this country 17,000,000 pounds which sold for about five million dollars—less than 30 cents a pound. And this was the answer of chemists and metallurgists to the demand for a light, permanent metal at moderate cost. What the future of aluminum may be we do not know. But being in abundance, the second of the solid elements and twice as large in amount as iron, its compounds can not possibly be exhausted.

Alizarin, which is one of the important vegetable dyes, was formerly obtained from madder, the root of a plant growing abundantly in the south of France and some other Mediterranean countries. The demand for it increased until thousands of acres were given over to the cultivation of the *Rubia tinctorum*. But in 1868 two chemists, Graebe and Liebermann, after long study, succeeded in preparing alizarin synthetically from anthraquinon, a coal-tar derivative. It drove from the market the natural alizarin. There was an outcry from those who had cultivated the crude material that their means of livelihood had been destroyed. But thenceforward the fertile fields which had been devoted to its growth were used to furnish foodstuffs to the country. A waste substance had been used and the old energy turned into better channels.

A similar history is that of indigo, one of the standard dyestuffs of our grandmothers—a product of the indigo plant. Adolf von Baeyer, chemist, of Munich, in 1870 overcame the difficulties of its synthetic formation and, from coal-tar again, by complicated methods prepared this substance, one of the most stable of our dyes. Other chemists have simplified the process until now it is formed in the factory, a rival of that from the field, and thus large tracts of land are released for other forms of agriculture.

If the past achievements of science give us hope that it can stay the drain upon our resources, we can gain encouragement by examining its present activities.

While doubtless much fuel has been wasted it is now being used much more economically than formerly. There is a tendency to centralize the evolution of heat and other forms of energy produced from burning coal. A large proportion of our coal is used in locomotives for the purpose of hauling more coal to the place of consumption. This can be saved by carrying the energy from the coal fields as electricity or gas. Even the conversion of coal into producer gas at the place it is used is a great advantage. The lowest grades of coal are employed, such as lignite, slack and culm, and the gas gives several times as much energy under a boiler as would the coal from which it is made. Again, our culm piles, the accumulations of years, are being moulded at slight expense into briquettes which are in many respects superior to coal as a fuel.

As a substitute for our vanishing gasoline we are looking toward alcohol. Although at present it can not compete in price, new sources are being sought by the chemist and it will undoubtedly become cheaper. Not only can the crude material for its manufacture be obtained from the grains but working processes have been announced, starting from the cellulose of sawdust and peat.

I need only refer to the value of our water power. It has been estimated that the United States has about 40 million horse power which is now available and four times this which can be developed. To get an equal amount of energy from our steam plants would require over 3,000 million tons of coal. Or, to state it in another way, by developing this water power, now not utilized, over three thousand million tons of coal can be saved—about four times our annual consumption.

With a possibility of the disappearance of available petroleum and even of coal, substitutes for these have been ardently sought in recent years or, if not complete substitutes, attempts are being made to find something which will decrease their excessive use.

As we all know, the luminosity of illuminating gas is due to minute particles of carbon which are heated to incandescence. A substitution of other solid materials in the hotter, though non-luminous, flame of the Bunsen burner—lime, platinum and zirconium—met with failures. Then came a German chemist, Auer von Welsbach, and discovered, through extensive investigations with the oxides of the rare earths, that while neither thorium nor cerium oxides were highly luminous, if one per cent. of cerium oxide is added to thorium oxide the product glows at high temperatures with great intensity. The gas mantle and incandescent light were the result, and with them a far greater degree of illumination, with the use of a fraction of the gas formerly used.

We are all acquainted with the results of the labors of science in the fields of acetylene and electric lighting, where energy is furnished by water power or where cheap coal can be burned miles away from the dazzling lights. Every city has its object lesson. Only one instance will be spoken of.

The deficiencies of the carbon-filament incandescent electric light bulb are known to all of us—its reddish light, its decrease in brilliancy with use, its comparatively short life and rather low efficiency. Most of us can testify to the superiority of the tungsten bulb, one of the latest productions of the chemist and electrician—its white light, its long life with but slightly lessened intensity, the comparatively low cost of the light per candle power.

From a relatively slightly known substance—material for the mineralogist's collection—the use of tungsten has rapidly increased. Forty-six tons of its ore were mined in the United States in 1900; in 1907, 1,640 tons; truly, in comparison with iron, copper and lead, an insignificant amount. But when we remember that one pound will make thousands of electric-light filaments we can comprehend that revolutionary results may follow. The ore is widely distributed in the Rocky Mountains, as far north as Alaska, and no prophecy can be made as to when it may become exhausted.

Tungsten has many other uses possibly less known to you; among them, as a material for small crucibles to be used in the electric furnace, and as a modifier of the properties of steel, the latter probably the most valuable. Tool steel containing tungsten holds its temper at high temperatures. Tools with a tungsten content of 16 per cent. to 20 per cent. can be used with the lathe running at such a speed that the chips are blued from the heat yet the temper of the tool is not affected. That is, in consequence of the high speed, about five times as much work can be accomplished as when high carbon steels are used, one man's labor being thus multiplied by five. Here again the metallurgical chemist has shown himself equal to the demand upon him, a demand for a new means of decreasing the drain upon a part of our resources.

What about the forests? Personally I have no fear. Aside from the methods of scientific forestry, which must necessarily come, other forces are acting. Although the chemist uses forest products as a source of supply, he need not be feared. He can utilize the waste wood —the stumps, the chips, the branches, the sawdust, material fit for nothing else. And he is daily perfecting chemical products to take the place of wood. Cement is one of these; of this the amount is increasing and the cost diminishing. In 1908 we made in the United States 51,072,612 barrels of Portland cement at a cost of $43,547,679, an increase over the preceding year of over two and a quarter million barrels with a decrease in cost of more than ten million dollars. In 1909 somewhat over sixty-two and one half million barrels were manufactured at about 80 cents per barrel as compared with 85 cents in 1908.

We are so accustomed to our wooden houses that we dread to have to give them up even when we know that in many other countries they are almost unknown. We are unmindful of Ruskin's dictum, "I would have our ordinary houses built to last," as well as, "built to be lovely, as rich and full of pleasantness as may be within and without." We are regardless of the thought that, instead of erecting a structure which can endure 50 to 100 years, it may be better to build for 500 to 1,000 years or more.

In other ways the chemist is conserving the forests; by guarding against one of the greatest dangers to our wooden edifices—fire—through fire-proofing processes, and against their bacterial foes, which cause decay, through wood preservatives. As to stopping the journey of our forests to the paper-mill, it appears not to be the time for that yet, but chemists are finding ways of replacing wood fiber in paper by others, notably those of grasses. Even if it should prove beyond the skill of the chemist and engineer to continue our present output of paper from the dwindling wood supply and should most of our Sunday papers be forced to curtail their issues, who will see in that any dire calamity?

Cement is frequently used to preserve not only wood, but in many places iron, and so conserves this material. Where more strength is required than concrete possesses, iron surrounded by cement has been found to last indefinitely. The process of reducing the crude iron from the ores has been steadily improved so that now, through such means as using the heat formerly wasted from the blast furnace to heat the air of the blast, to make steam and to dry the air before it is blown into the furnace, but a fraction of the coal is required that was formerly necessary. Similar savings have been made in other parts of the metallurgical field; for instance, in the recovery of gold and silver during the treatment of copper and lead ores, several million dollars worth being thus annually obtained, and this by the old methods would have been for the most part wasted.

The loss of by-products in the manufacture of coke has been referred to; but closer chemical supervision is rapidly reducing this. In 1905 over thirty-seven million tons of coal were coked in the United States, but less than 9 per cent. in ovens where these by-products were preserved. Two years later the amount coked in by-product ovens had increased about one half.

Foreign chemical engineers are setting us a praiseworthy example. In Gelsenkirchen, Germany, the coke ovens furnish illuminating gas to surrounding cities and villages at 23 cents per 1,000 cubic feet. Each ton of coal yields three to three and one half gallons of benzene, a valuable substitute for gasoline as a producer of heat and energy. From the recovered tar are separated naphthalene, toluene and anthracene from which are derived the brilliant coal-tar colors and many synthetic medicinal compounds, also disinfectants and preservatives like carbolic and benzoic acids. In Germany the coal coked so that the by-products could be recovered was 30 per cent. in 1900; 82 per cent. in 1909.

Our chemists are devising means to prevent the contamination of the atmosphere by industrial wastes. Witness the Sulphur, Copper and Iron Company at Ducktown, Tenn., whose blast furnace gases contain a high percentage of sulphur dioxide because of the abundance of sulphur in the ores. Instead of, as formerly, allowing this to escape to poison the surrounding vegetation it is caught and converted into sulphuric acid. One hundred and sixty tons are produced daily, of high purity; a waste product has been converted into an article of commerce for which there is a constant demand.

In agriculture the general outlook is highly encouraging. True, much time will pass before the agricultural chemist is estimated at his real value, but even now the farmer is making use of his assistance and asking for his aid with increasing frequency. He is learning that the old "rule-of-thumb" methods are unprofitable, and when he is convinced that science can more abundantly fill his purse, the end that we desire is in sight. It is within the remembrance of most of us what a change has taken place in Iowa, within the past fifteen or twenty years with respect to fertilizers—the putting back into the bosom of mother nature the nourishing elements of which our crops have deprived her. Fortunately our farms are still exceptionally fertile and by scientific treatment we of Iowa may not be reduced to that dependence upon artificial plant food which is so painfully noticeable in New England and other eastern states. But our pride in our soil should not lead us to overlook our imperfections. When we know that our average wheat crop is, for the country, only twelve to fifteen bushels to the acre, that of England, the Netherlands and Denmark over twice that and that on some of our experimental farms it runs up to seventy to eighty bushels, it should make us pause for serious reflection. On the other hand, if, as we are told, the average crop of the Romans was but four to five bushels we can take courage and strive for better results.

I have spoken of new means of getting nitrogen, one of the three plant nutrients most apt to be deficient. A second, potassium, occurs abundantly in feldspars in a comparatively insoluble form. Recent experiments by chemists, however, indicate that through very fine grinding the door is unlocked which will set it free in a form which the plant can assimilate. For the third nutrient, phosphoric acid, we must probably depend upon re-using that taken up by the plant or upon undeveloped deposits. Happily, we have such ones. Announcement has just been made by geologists of large phosphate beds in several of our western states. Knowing how nearly we have approached phosphate poverty we can take measures to more properly protect them.

With these materials, with the systematic study which is being carried on in government laboratories, in experiment stations, in agricultural colleges and universities of the chemistry of the soil and of the food and metabolism of plants, with the industry of the fertilizer chemists, and with the awakening of the farmer to the needs of such knowledge, we can hopefully expect a bountiful food supply for the world's table.

The aid of science is noteworthy in increasing human vitality,—one of the principal factors in national efficiency, and a form of conservation. In the sixteenth century the average length of human life is estimated as being between 18 and 20 years; to-day it is between 38 and 40 years. Modern hygiene is markedly lowering mortality and lessening illness. Compare the former death rate of Havana, 50 to 100 per 1,000, with the present one which is but little more than that of our northern cities. Note the disappearance of yellow fever and cholera from the Isthmus of Panama and the fall of the death rate to one third of that of the French administration. Known to everybody is the successful fight which is being waged to decrease the ravages of small-pox, tuberculosis, diphtheria, meningitis and the hook-worm.

The food of the nation is being studied as never before by hundreds of chemists; the actual needs of the body are being determined, the kinds and amounts of food adapted to particular conditions are learned, dangerous and adulterated foods are proscribed. Through the studies of milk and children's foods by physiological chemists the mortality of infants has been greatly diminished. In all these conflicts against disease the chemists are in the front of the battle. A strenuous campaign of education must be carried on, but already the light begins to shine into the dark places.

In this broad field of conservation where the opportunities for labor are so great how are we, as educators, doing our part? Are we merely applying our scientific knowledge, or are we also training others for service—the young people of this university?

Regardless of current discussions as to woman's proper place in the social fabric, it is certain that society has caused her to specialize as the conserver of the home. Her position may be modified in the future, but it will be long years before she abdicates this regal station. I do not mean that she should remain a household drudge, confined to the walls of the kitchen, nor do I intimate that all women can, or care to, be so distinguished. But Woman—*das Ewig-Weibliche*—is destined long to preside, the goddess of the family, as in the days of Solomon, the Wise, for, as then,

Her price is far above rubies.
Her children arise up and call her blessed;
Her husband also, and he praiseth her.

In common with other large universities we are doing our best for the young men, preparing them for the professions or the business to which they will be called—physicians, lawyers, dentists, engineers, chemists, accountants—fitting them to aid in the conservation of material resources, of liberty and of life.

When we are asked regarding our stewardship of the young women a discreet silence may be the safest reply. We are giving them disciplinary studies, a general education in subjects interesting alike to man or woman, an opportunity to develop the social instincts, to gain by association with educated people, and to become more at ease in society. But we look in vain for a careful training in the field where woman should be supreme, an opportunity for any detailed study of chemistry with the related sections of physics, bacteriology and physiology, as applied to food and diet, disinfection and disease, particularly diseases of children, general prophylaxis, sanitary construction, the disposal of wastes, and the manifold other problems of the home. As homekeeper much of the financial success of the average family will depend upon her. Where is she getting the instruction? Most men are only indirectly interested in such problems and therefore if woman can not, or will not, solve them they will be unsuccessfully met. It is true that most of them are merely applications of scientific principles, and that somewhere in the university these principles are taught. Yet nowhere are they correlated to make a systematic course for this large proportion of our students. The men of the University of Iowa may make good husbands, but, as a rule, they will not be able dieticians; the women may make the best of wives but, in that case, the university can claim but a small part of the credit for it. The University of Iowa is missing its great opportunity.

In all this I am not pleading for the special training of teachers and experts; only for aid in the conservation which shall supply our needs, through the symmetrical development of our students and their best preparation for their life-work.

I have spoken of a few of the means used by science to conserve our resources, but they are typical of hundreds of others carried on all over the world by thousands of men with chemical training and working by scientific methods. From this present activity we can look ahead and predict some of the tasks next to be accomplished. Were the time sufficient, it would be interesting to discuss them—the probability of the synthetic production in the laboratory of many of our foods now only formed by the slow processes of nature; a system of intensive agriculture whereby our crops will be increased many fold;

more perfect means of storage and preservation of foods so that we may at any time avail ourselves of them in their natural freshness; the almost complete control of disease; the utilization of the hitherto uncontrolled energy of the sun through the collection of its heat; and the practical use of the force of the tides. These, however, we shall have to pass by for the present. Nor shall I dwell upon the possibilities of that almost unknown force locked up in the atom and revealing itself as radioactivity, far superior to any other known power. Whether we shall ever be able to liberate and control it we can not even surmise.

In all this I have emphasized the materialistic side, the gaining of dollars and cents, of all that can contribute to comfort and ease, and all to result from applied science. Do not, therefore, regard me as belittling that other aspect—the pursuit of knowledge for its own sake, the irrepressible striving to raise one's self through earnest effort toward the level of the Omniscient, the feeling of Paracelsus in his laboratory,

> I still must hoard and heap and class all truths
> With one ulterior purpose: I must know!
> for night is come
> And I betake myself to study again,
> Till patient searchings after hidden lore
> Half wring some bright truth from its prison; my frame
> Trembles, my forehead's veins swell out, my hair
> Tingles for triumph. Slow and sure the morn
> Shall break on my pent room and dwindling lamp
> And furnace dead, and scattered earths and ores;
> When, with a failing heart and throbbing brow,
> I must review my captured truth, sum up
> Its value, trace what end to what begins,
> Its present power with eventual bearings,
> Latent affinities, the view it opens,
> And its full length in perfecting my scheme.

For our hearts still harmonize with the outcry of the alchemist,

> I shall arrive! what time, what circuit first,
> I ask not: but unless God send his hail
> Or blinding fireballs, sleet or stifling snow,
> In some time, his good time, I shall arrive.
> He guides me and the bird. In his good time!

And it is through this patient and persistent toil that in the future, as in the past, man will triumph over the forces of nature,

> For these things tend still upward, progress is
> The law of life, man is not Man as yet. . . .
> But when full roused, each giant-limb awake,
> Each sinew strung, the great heart pulsing fast,
> He shall start up and stand on his own earth,
> Then shall his long triumphant march begin,
> Thence shall his being date—thus wholly roused,
> What he achieves shall be set down to him.

THE PROGRESS OF SCIENCE

ABOUT DISMISSING PROFESSORS

The president of one of the leading universities in the east and the president of one of the leading state universities have recently expressed opinions in regard to the tenure of office of the university professor which deserve careful attention. In his annual report to the trustees, President Butler, of Columbia University, writes:

A teacher or investigator who offends against common morality has destroyed his academic usefulness, whatever may be his intellectual attainments. A teacher who offends against the plain dictates of common sense is in like situation. A teacher who can not give to the institution which maintains him common loyalty and that kind of service which loyalty implies, ought not to be retained through fear of clamor or of criticism. Then, too, a university teacher owes a decent respect to the opinions of mankind.

In the issue of *Science* for February 17, President Van Hise, of the University of Wisconsin, says:

. . . the instructional force of a university, both young and old, must be efficient. Whether or not a man is retained in a faculty should depend upon his capacity to meet his duty to the institution. There is no possible excuse for retaining in the staff of a university an inefficient man.

It is certainly desirable that professors should be moral, efficient, sensible and loyal; they should have even other qualifications than those which they share with domestic servants. But it is a far cry from this to the claim that the president should dismiss professors whenever they seem to him to lack these traits. Such a claim obviously traverses academic traditions. Professors receive their appointments at the average age of forty years. If a mistake is made, it is the fault of those who appoint, and they should accept the responsibility. Professors who prove to be less competent in the management of large classes in the undergraduate college and in the professional schools should be relieved from them, but it is more economical to pay an occasional professor his salary without full return, than to place the whole university under the law of supply and demand. By the nature of things, some professors are less competent than the average of them all, and any university could temporarily raise the average by replacing ten per cent. of the faculty. But it would be the old story of killing the hen that lays the golden eggs.

President Van Hise says:

The question now arises as to what should be done in the case of a man of professorial rank, whether full, associate or assistant, who is not efficient. Not infrequently papers with reference to this subject appear to assume that universities exist for the instructional force; that the main thing is to give that force a comfortable and happy time, an opportunity for a somewhat easy existence as a teacher, leisure for browsing through literature, and long vacations.

A scientific man should give references to his authorities; but President Van Hise apparently thinks that professors in general hold such opinions and would like to form a privileged class. According to President Butler they do form such a class. He writes in his report:

The happenings of the past decade [that is since he became president] have made the lot of a member of the permanent teaching staff of Columbia University one that is indeed fortunate. . . . It may be that there is some other career that is equally fortunate, but if so, the fact does not appear to obtrude itself upon the public attention.

President Butler, however, seems to realize that professors do not share his opinion as to their happy lot, for in an editorial article in the last *Educational Review* he writes:

> Truly the academic animal is a queer beast. If he can not have something at which to growl and snarl, he will growl and snarl at nothing at all.

In the *Educational Review* for October last he quotes from *The Nation* the following:

> There is a fine opening for a new institution to show what a college can be wherein the personal domination by the president is abandoned, and in its stead we have a company of gentlemen and scholars working together, with the president simply as the efficient center of inspiration and cooperation.

and with some inconsistency remarks:

> Concerning this statement two things may be said with a considerable amount of emphasis. The first is that the condition described in the last four lines is precisely what is to be found at every American college and university that is worthy of the name, and that no evidence to the contrary has ever been produced by anybody. The second is that, while the attempt to create a contrary impression may be originally due to ignorance, when persisted in it can only be attributed to malice.

Permanent tenure of office for the professor is not such a unique state of privilege as President Van Hise imagines. A president's wife has permanent tenure of office; he can not dismiss her because he regards her as inefficient or because he prefers another woman. In the army and navy, in the highest courts, to a certain extent in the civil service of every country, there is permanence of office. Indeed it is nowhere completely disregarded; service is always a valid claim for continued employment. Perhaps one wife in fifty is divorced by the courts, one army officer in a hundred court-marshalled, one judge in a thousand impeached; but such actions are taken after definite charges and opportunity for defence.

Permanent tenure of office is intended to improve the service, not to demoralize it. It is attached to honorable offices, where public spirit and self-sacrifice are demanded, and the wages do not measure the performance. In Germany, France and Great Britain the permanence of tenure has given dignity and honor to the university chair, attracting to it the ablest men and setting them free to do their best work. In this country the better the institution, the more permanent has been the tenure of office. Up to the time of the writing of President Butler's report only one professor had ever been dismissed from Columbia University, and then it was for entering the confederate army.

It is possible to adduce arguments for the introduction of the competitive system into the university. Thus President Butler holds that it is undesirable to pay equal salaries. He says:

> In my judgment such a policy would fill the university with mediocrities and render it impossible to make that special provision for distinction and for genius which the trustees ought always to be able to make.

But it appears that the general course of social evolution is not towards competition. In the university it would probably be adverse to the finer traits of scholarship and character, most of all when, as under our present system, the competition would be for the favor of presidents and trustees. The president may assume superhuman responsibilities, but he is after all human in his limitations. He may regard common sense as agreement with him, common loyalty as subservience to him, respect for the opinions of mankind as deference to that small portion of mankind which has money to give.

If there is to be competition in order to retain university chairs, then the university must be prepared to forego able men or to compete with other professions in the rewards it gives. It must offer prizes commensurate with those of engineering, medicine and law, namely, salaries as large as a hundred thousand dollars a year. It is further true that under these circumstances a man must be judged by his peers.

There are doubtless advantages in a system of severe competition for large prizes under honorable conditions, as well as in permanent tenure of office with small salaries and a free life; but confusion and harm result from running with the hare and hunting with the hounds. A university which dismisses professors when the president thinks that they are inefficient or lack common sense is parasitic on the great academic traditions of the past and of other nations. A single university which acts in this way will in the end obtain a faculty consisting of a few adventurers, a few sycophants and a crowd of mediocrities. If all universities adopt such a policy, while retaining their present meager salaries and systems of autocratic control, then able men will not embark on such rotten ships. They will carry forward scientific work in connection with industry and will attract as apprentices those competent to learn the ways of research.

THE GRADUATE COLLEGE OF PRINCETON UNIVERSITY

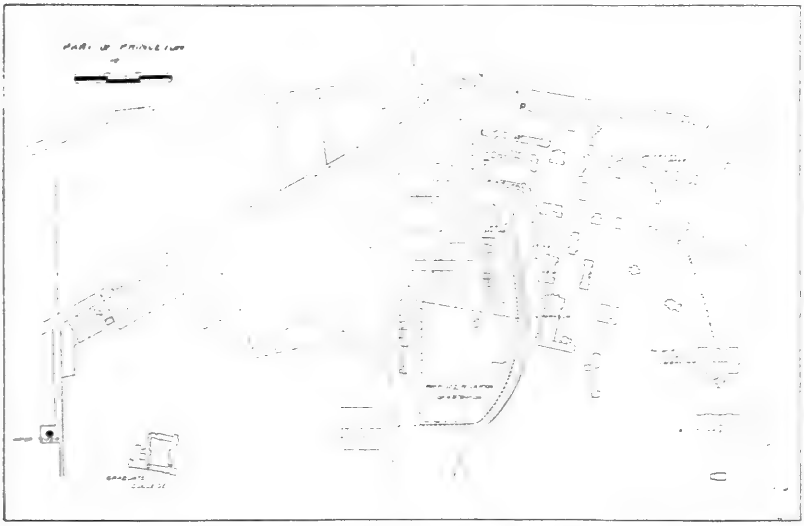
PRINCETON UNIVERSITY has now no president and could get on admirably without one. It is true that the professors at Princeton who disagreed with the president and opposed his policies were not dismissed for lack of common sense and common loyalty. On the contrary, they won victories in a fair field where each side contended for principles. It is also true that at Princeton one professor has been able, first with and then without the favor of the administration, to carry out the plans which he formed. But the question arises whether Princeton could not to advantage place the control of its policies formally in the hands of its faculties.

If the new graduate college should, like the colleges of the English universities on which it is confessedly modelled, be placed in charge of its fellows and professors, letting them be responsible both for appointments and for finances, then there could and would be gathered there a group of scholars such as has not been seen in this country since the early days of the Johns Hopkins University. There are but few of the younger men on whom the future of scholarship and research depends who would not gladly go to such a college, whether as teachers or as students.

The graduate college of which Professor West has dreamed, for which he has worked and which he has now made an accomplished fact is described by him in the last number of *The Century Magazine*, with special reference to the ideal of the scholar's life. Thanks to the bequest of Mrs. Swan, to the liberal gift of Mr. Proctor followed by gifts from other alumni, to the subscriptions to a memorial of Grover Cleveland, who was the first chairman of the committee of the graduate college, and to the large endowment left by Mr. Wyman, the graduate college has resources amounting to between three and four million dollars. Of this sum about six hundred thousand dollars will be spent on the buildings, including the Cleveland memorial tower, the Proctor dining hall and the Thomson residential court. The greater part of Mr. Proctor's gift and practically the whole of the Wyman bequest will be devoted to the endowment of professorships, fellowships and opportunities for research and publication. With the library, the laboratories and the academic buildings of the university, with the beauty of its architecture, the charm of the open country, the academic and national traditions of the place, the infant college is surely endowed by the fairies with all ideal gifts.

Professor West has been charged with exploiting the externals of culture, and it may be that he exhibits a touch of the pedantry that he ridicules. But his article in *The Century* is broad and sympathetic; his plans and ideals

Design for the Graduate College of Princeton University.



Ground Plan of the Buildings of Princeton University, showing the situation of the Graduate College.

are both fine and possible. It is not desirable for students to sleep in dark closets and eat at cheap boarding-houses, or for professors to live in hidden little flats and wash the dishes. Beauty and dignity are as far removed from extravagant luxury as from squalor. Professor West justly says:

> Three elements compose the graduate college. Foremost is a body of first-rate professors, to be added to others now in the faculty, interesting men, scholars of high power, eminent in their subjects, and able to waken young men. Do we need to say this is the capital A in the alphabet? If so, let it be said again and underscored, because it would be absurd to say anything else. The second element is a company of students of high ability. . . . The third element is the buildings, the material home wherein this community shall find the realization of its desires.

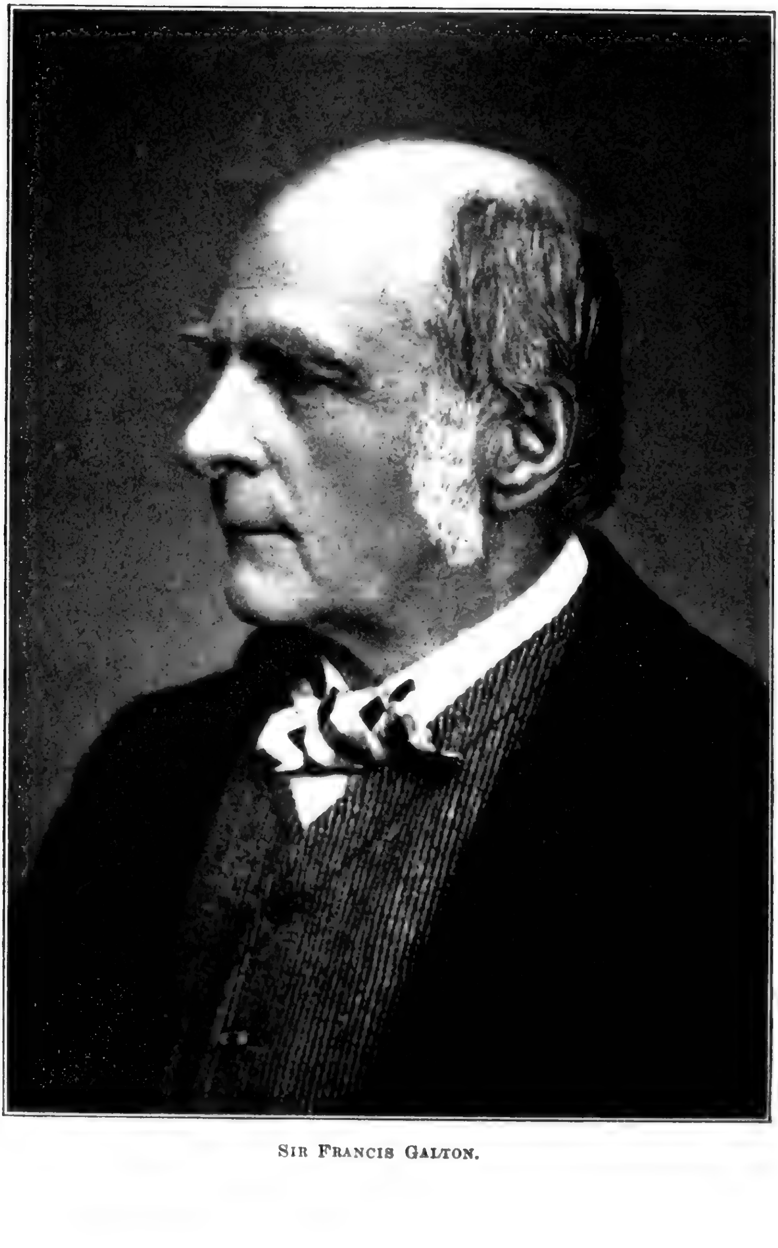
He also writes:

> The truth at the heart of this history is that a university is a community, and a community made up of teachers and learners, an actual *respublica litteraria* (to quote an old name for the University of Cambridge), and that in this established and continuing society lies the safety of learning as a self-perpetuating force and the promise of learning as a usable force in the world.

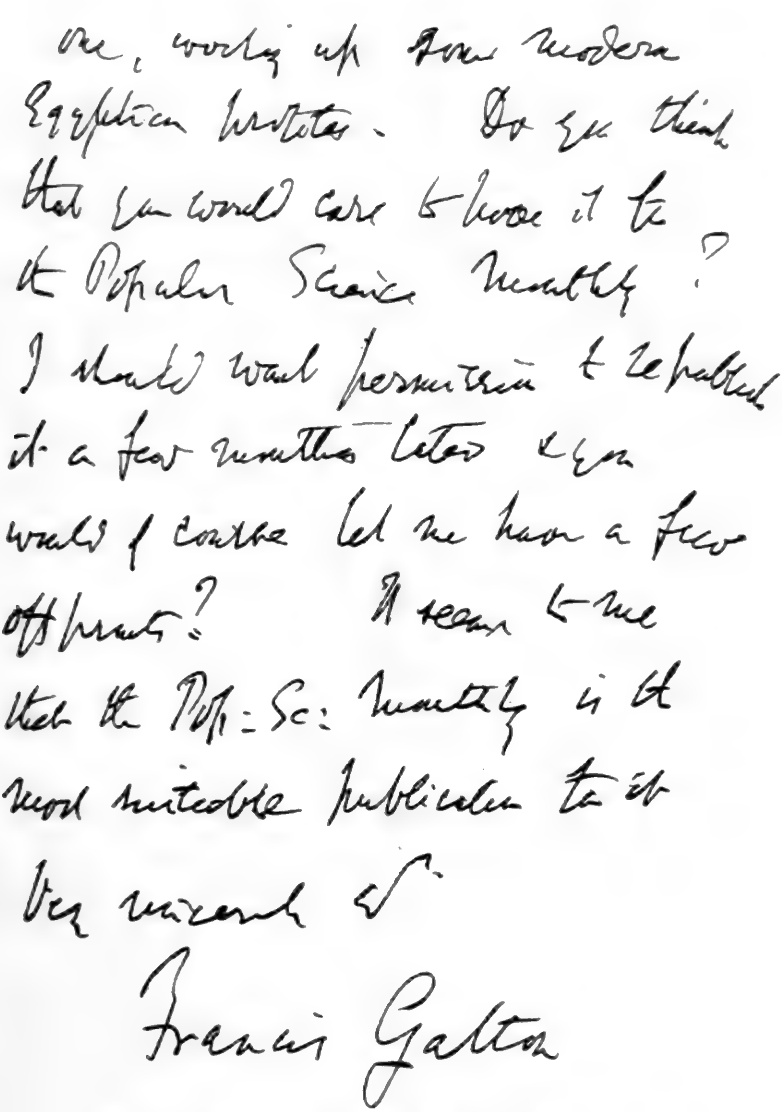
FRANCIS GALTON

Francis Galton is now dead at the age of nearly eighty-nine years. One more of the great men who gave distinction to the Victorian era has been lost from the small surviving group which in science includes Hooker, now ninety-four years old, Wallace, eighty-nine years old, and Lister, eighty-four years old. In the generation a decade younger there are eminent men still living—Avebury, Rayleigh, Crookes, Roscoe, Geikie and other men of science—and perhaps Great Britain better than any other nation retains the fertility for the production of genius. It may indeed be that the men active in our own day are no less able than those of the nineteenth century; that remains for the next generation to decide. For us, however, these men—Darwin, Kelvin and the great company of leaders in science and letters of the Victorian era—are as giants whose stature we can not reach.

Galton published in 1909 a volume entitled "Memories of my Life," which gives a characteristic and charming account of his varied work and experiences. He was of Quaker descent,



Sir Francis Galton.


me, working up from modern
Egyptian statistics. Do you think
that you would care to have it in
the Popular Science Monthly?
I should want permission to republish
it a few months later & you
would of course let me have a few
offprints? It seems to me
that the Pop: Sc: Monthly is the
most suitable publication for it
Very sincerely yrs
Francis Galton

PART OF AN AUTOGRAPH LETTER FROM SIR FRANCIS GALTON, written in his eighty-ninth year.

and, as is fitting, a member of a distinguished family. The tenets of his grandfather did not prevent him from making a large fortune by the sale of arms in time of war; he wrote about birds and was skilled in statistics. One of his grandsons was Sir Douglas Galton, the eminent engineer. On his mother's side Francis Galton was a grandson of Erasmus Darwin and a half cousin of Charles Darwin. His wife also belonged to a distinguished family—she was the daughter of the dean of Peterborough and the sister of the master of Trinity College; it is the irony of fate that they have left no lines of descent.

It is not needful to review here Galton's remarkable contributions to science, nor would it be possible to do so. At first sight his work seems to be disconnected; but it represents a normal evolution and has one fundamental basis, namely, the application of quantitative methods to phenomena theretofore outside their control. Beginning with geographical explorations and by the inevitable nature of the man improvements in the conditions under which such explorations are carried forward, he next took up the unstable phenomena of meteorology, devising the graphic method of the weather chart and inventing new instruments. But he soon passed to the still more complicated phenomena of biology, anthropology and psychology. Here his genius touched many subjects. Mental imagery, composite photographs and fingerprints are familiar to all. His great contribution is the study of human heredity by exact methods and its application to the improvement of the race. Galton's word "eugenics" may be soiled by ignoble use; but his work is one of the most original creations of pure science and at the same time one of its most important applications—so great indeed that Galton's body may some day be taken from the quiet churchyard where it lies to be placed beside Darwin and Kelvin in Westminster Abbey.

Galton united certain characteristics which the disciples of George Fox seem to have bred into their blood with the traits which those who knew Charles Darwin found in him. A few days before his death the present writer had the privilege of presenting his name for honorary membership in an academy of sciences to succeed William James. These two men are the greatest whom he has known. James possessed the more complicated personality; but they had certain common traits a combination of perfect aristocracy with complete democracy, directness, kindliness, generosity and nobility beyond all measure. It has been said that eugenics is futile because it can not define its end. But the answer is simple—we want men like William James and Francis Galton.

SCIENTIFIC ITEMS

We record with regret the deaths of Professor Leonard Parker Kinnicutt, director of the department of chemistry in the Worcester Polytechnic Institute; of Dr. Edward Gameliel Janeway, professor of medicine and dean of the University and Bellevue Hospital Medical College, and of Dr. Willibald A. Nagel, professor of physiology at Rostock.

Sir Joseph Larmor, Lucasian professor of mathematics at Cambridge University and secretary of the Royal Society, has accepted an invitation to become the unionist candidate for the vacancy in the parliametary representation of Cambridge University.—Dr. W. K. Röntgen, professor of physics at Munich, and Dr. Ewald Hering, professor of physiology at Leipzig, have been appointed knights of the Prussian order pour le mérite. Dr. Gustav Retzius, formerly professor of anatomy at Stockholm, has been appointed a foreign knight of this order.—Dr. Samuel G. Dixon, professor of hygiene in the University of Pennsylvania, and Dr. George Wharton Pepper, professor of law, have been elected trustees of the university.

It was announced on January 20 that Mr. Andrew Carnegie had added $10,000.000 to the endowment fund of the Carnegie Institution of Washington. The institution was established in 1902 with a gift of $10,000,000, and Mr. Carnegie recently added $2.000,000. These gifts consist of preferred bonds of the Steel Corporation bearing five per cent. interest and their market value is considerably above their par value. Mr. Carnegie's gifts to public purposes now amount to about $200,000,000.

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THE GENESIS OF THE LAW OF GRAVITY

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SINCE the earliest ages man has been interested in the world outside of himself. Thunderstorms, waterfalls, winds, waves, fire, the starry heavens have aroused his wonder, admiration or fear.

During the earlier stages of racial development the simplest phenomenon was explained by reference to some arbitrary power, and soon gods and demigods were conceived of as presiding over the agencies of nature. Later men who had wrested some of her secrets from nature or had won some victory over her were exalted to the position of heroes and worshipped, while their exploits, greatly magnified, became part of the legendary history of the race. Slowly man began to realize that there is a constancy about nature that may be expressed in general statements. These statements were often vaguely expressed as, "Nature abhors a vacuum," "Water and fire are antagonistic," "There are three elements, earth, air and water" or "earth, fire and water." These crude beginnings led to more careful and more systematic study of nature, and to more exact statements of what we now call the laws of nature.

It took long ages—perhaps we have not even yet reached the goal—for man to realize that the content of his study is here objective, so that the method of study must be *inductive* and not *deductive*. This being the case, the conclusions arrived at must be allowed to shape themselves regardless of consequences to antecedent beliefs. Thus it happened that the study of nature has been for ages hampered by many a prejudice and by many a "Thou shalt not" from churchman and philosopher.

Another and perhaps greater impediment than the inertia of the human mind was the ravage wrought by war and time. Could each age have the full benefit of all preceding ages, could man in very truth be "the heir of all the ages," there would be no lost arts and the world would not have to learn over and over again lessons once mastered.

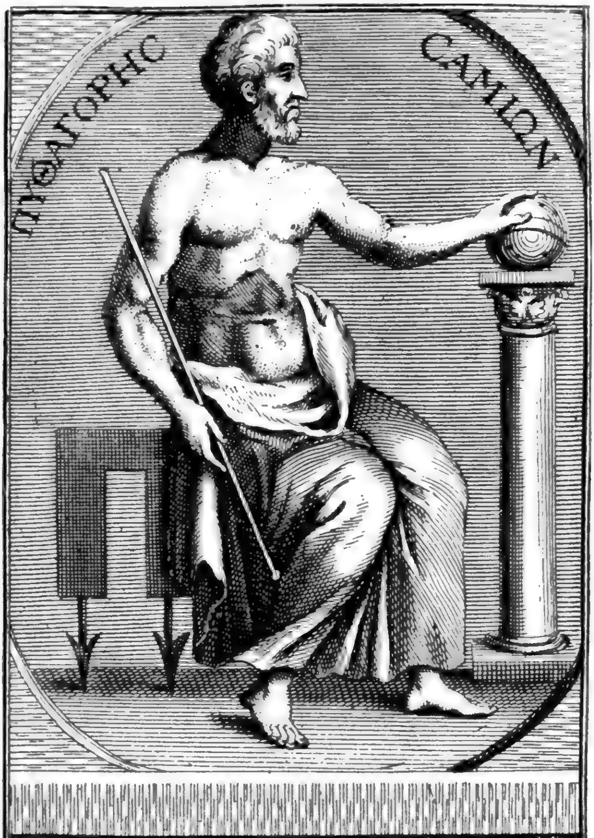
A last impediment may be mentioned, peculiar perhaps to problems like the discovery of the law under discussion. It is hard for a worker in any field not to attempt to reach forward to the final solution of his problem. This is true even if the data for generalization be most meager. Thus it has happened time after time that ill-formed theories have been advanced even by great minds. Indeed the very greatness of the man whose name the theory bears proves an added obstacle. Thus the dicta of Aristotle held sway for centuries and even Galileo's brilliant experiments at the leaning tower of Pisa could scarce overcome the false Aristotelian theory of falling bodies. Another example is Newton's theory of light which survived at least a hundred years, simply because it was Newton's.

We shall in the present paper seek to trace the history of the problem which found its final answer in Newton's *Law of Universal Gravitation.* This law may be stated in the following familiar terms: "*Every particle of matter attracts every other particle of matter with a force proportional to the mass of each and to the inverse square of the distance between them.*"

In tracing the history of how the race came into a clear knowledge of this law we find two streams with their headwaters far back in history, slowly gathering volume age by age and finally uniting and bearing the world on to the long-sought-for goal. The first of these streams may be called *the study of pure motion,* or of *kinematics,* the second *the study of the causes of motion,* or of *dynamics.* The first is best illustrated by the history of astronomy as developed down to the seventeenth century, while the second is best illustrated by the history of mechanics during the same period.

In astronomy we shall pay attention only to those persons whose work has a bearing upon the present problem. The first name of worth seems to be that of Thales of Miletus (640–546 B.C.). With remarkable clearness he maintained the sphericity of the earth, the present theory of lunar eclipses, and the correct view regarding the source of the light received from the earth's satellite. He also suggested that the stars may be regarded as being of the same material as the earth. Thales was followed by his disciple, Anaximander (611–547), who was the first of the ancients to view the heavens with the eye of a philosopher. His name should be immortal, for it was he who first suggested that the earth moves about the sun as a center, a doctrine which became one of the tenets of the Ionian school.

Perhaps rapid progress might have been made in the explanation by natural causes of the phenomena of the heavens, but soon the jealous



PYTAGORAS
Philosophiam primus hoc est Sapientiam studiosam appellavit
Ex nummo æreo in Thesauro Christina Reginæ Aug

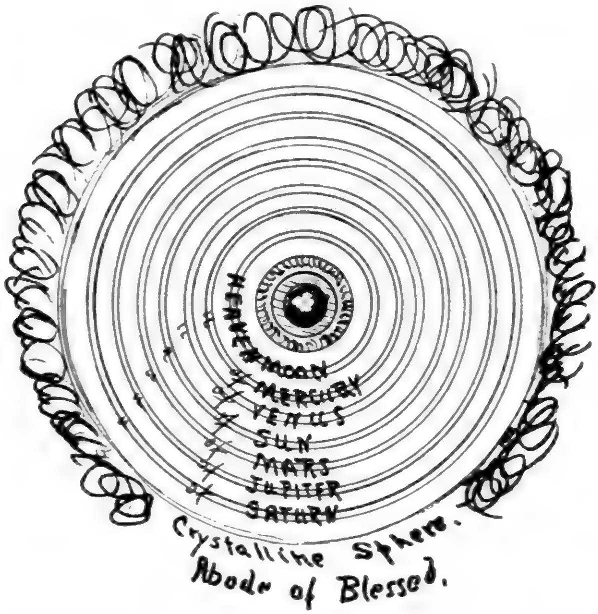
ire of the Athenians was aroused in behalf of their gods. As a result, history would have claimed the first martyr to scientific truth in the person of Anaxagoras (500–428), had not the great Pericles interposed in his behalf. Even so, the death penalty was but exchanged for that of banishment.

Another disciple of Thales was the illustrious Pythagoras (572–400), who not only held the views of his master, but, from observations on the altitude of the stars, measured in different places, demonstrated that the earth was round, or, at least, not flat. He conceived Venus to be both the morning and evening star—a view lost sight of, later, as shown by the double name, Lucifer and Hesperus, long applied to this planet. Most remarkable, perhaps, was his doctrine of the diurnal rotation of the earth and its annual motion about the sun. Less substantial, but longer-lived, was his fanciful notion of the harmony of

PTOLEMY.

the spheres. He conceived each planet as held in place by being fixed in a celestial crystalline sphere which, in its rotation about the sun as center, carried the planet with it. Having observed that the planets move at different rates, it followed that the various spheres had different rates of rotation, and Pythagoras believed that some law controlled their motions. This he expressed by supposing that each sphere emitted sounds or notes like the strings of a harp, and the harmony was expressed by the belief that the several notes united in a beautiful celestial harmony of most exquisite music. More fantastic than suggestive, yet here in the far-away dawn of scientific history is the foreshadowing of the great thought which two millenniums later was given in Newton's universal law of gravitation.

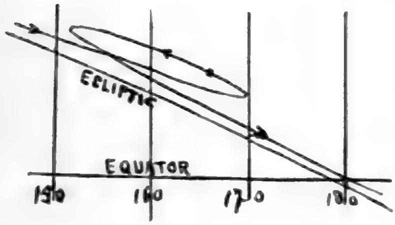
The fate of Anaxagoras warned Pythagoras against being too overt



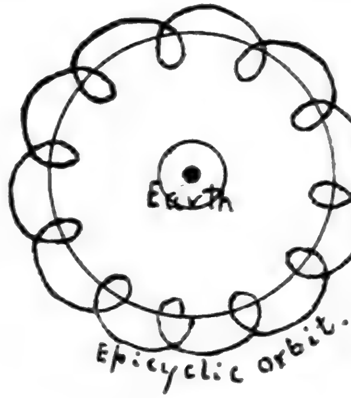
Ptolemaic System.

in his public teaching, so that much that he taught was under the seal of secrecy. He also sought greater freedom by removing from Samos to Italy.

It might be expected that with so much to build upon the genius of Aristotle (384–322) would have accomplished great things in astronomical science. But not so! For some reason he rejected the theories of Pythagoras and, although he is said to have come into possession of great stores of Chaldean observations, on the capture of Babylon by Alexander the Great, he made no use of them. Perhaps the task of



Apparent Path of Mars.



mastering these treasures was too great, perhaps his studies in anatomy and metaphysics prevented, but be that as it may, it must be acknowledged that his few pronouncements on physical science were for the most part erroneous and proved hindrances and not helps to those who followed him.

With the founding of the schools of Alexandria in the palmy days of the Ptolemys astronomy became a science. It was during this period that simultaneous measurements were made upon the altitude of the sun at Alexandria and Syene. At the latter place the sun at the summer solstice was on the zenith and at the former place 7° 12′ therefrom. From this and the known distance between stations the circumference of the earth was calculated as 250,000 stadia or 28,000 miles. This measurement was first made by Eratosthenes (276–196) and places him in the first rank in the Hall of Fame.

The centuries immediately preceding and following the beginning of the Christian era mark the rise both of astronomy and of geometry. It was probably due to progress in the latter science that Hipparchus (190–120 B.C.) and, later, Ptolemy (A.D. 120–170), were led to propound the system that still bears their names. This was a far more ambitious system than any that had preceded it, and sought, for the first time perhaps, to describe the exact path of the heavenly bodies. From our vantage point of wider knowledge it is easy to see its absurdities. Hasty judgment, however, must not be passed either upon its founders or upon the system itself.

In the first place, it was based upon observations; in other words, it was a generalization from data.

Secondly, it satisfactorily explained the observations contained in the premises.

Thirdly, it made possible the forecasting of eclipses.

The characteristics of the system may be given as follows:

1. The earth is a globe set immovable at the center of the celestial sphere—which sphere carries the fixed stars and revolves once per day.

2. The size of the earth is insignificant in comparison with that of the celestial sphere.

3. Seven planets revolve around the earth in the following order—the moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn.

4. The moon and sun move in excentric circles, the rest in epicycles.

Of the several considerations that must have induced the Alexandrian school to adopt this system we may note:

I. The Pythagorean system called for a moving earth, the Ptolemaic did not.

II. The observed motions of the planets were explained by the Ptolemaic system, and, while it is true that the Pythagorean system was capable of this also, it does not appear that the test by actual calculation had been made.

III. The system seemed adequate, was geocentric and appealed to the popular imagination.

Some of the more obvious criticisms of the system may be mentioned:

I. The ancients believed the sun to be larger than the earth—it would be more likely to be the center of the system.

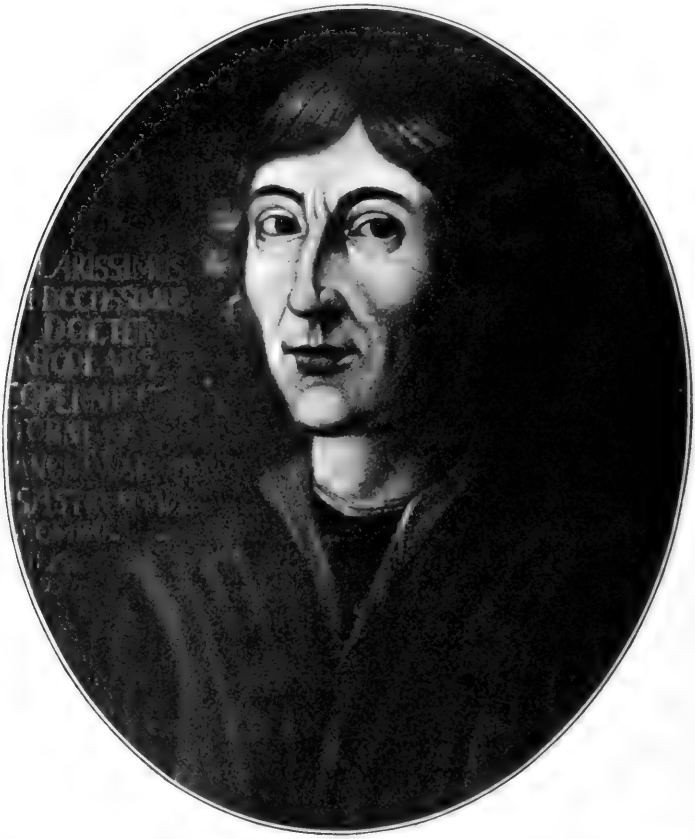
II. The diurnal motion of the earth offered a simple explanation of the apparent motion of the heavens—the simple should prevail when opposed to the complex.

III. The Pythagorean system gave the same law of motion (the circle) to all the members of the system, while in the Ptolemaic system the moon and sun moved in circles and the rest in epicycles.

The cumbersome Ptolemaic system, having been adopted, became with the passage of time deeply rooted in the philosophy and religion of the race. Its complexity became greater and greater, for with more accurate observations came the necessity of adding "cycle on epicycle, orb on orb" to keep track of the required corrections. It is not surprising, therefore, to find Alphonso X., in the thirteenth century, when contemplating the system, exclaiming, "if the Deity had called him to His councils at the creation of the world, he could have given Him good advice." Indeed the system finally crumbled and fell from the very weight of its superstructure.

We have spoken of the ravages of time and of war as hindering the progress of knowledge. We have now to note the greatest calamity that has in modern history overtaken the cause of human knowledge. In the third century before Christ, was founded the Alexandrian library with its treasures of art, of literature and of science collected from every part of the known world. Century by century it grew, and could it have survived what untold treasures would have been ours to-day! But in the seventh century A.D. the Caliph Omar in a day reduced to ashes this storehouse of wisdom, and by one act set the world back a thousand years. Perhaps this disaster can be overrated; perhaps, in the dissemination of copies of the old masters, the Alexandrian library had done its real work; but to me it seems otherwise; for many a priceless gem of literature and of science must have perished in the wanton Arab's destruction. As a single example, it is doubtless due to this cause that we have none of the astronomical writings of Hipparchus.

To Alphonso X., of Castile, belongs the honor of being the first European monarch to foster astronomy. In the thirteenth century he founded a college in Toledo, and gathered together savants from all parts of his realm. From the Arabs they acquired much both in mathematics and in astronomy. Original sources were also sought out in the Greek. Other schools were rapidly established and centers of



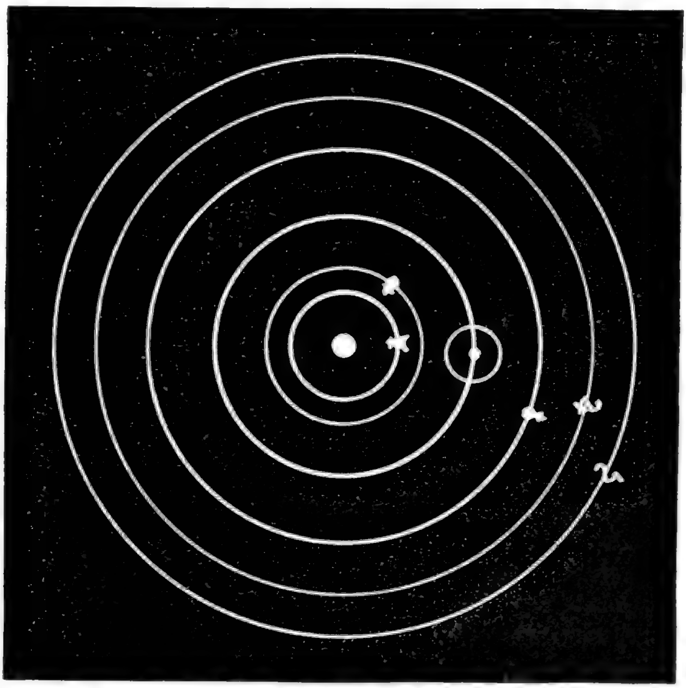
scientific culture formed. Among the notable workers and thinkers of the thirteenth and fourteenth centuries were Roger Bacon (1214–1292) in Cambridge and Paris, John Müller of Königsberg (1436–1476), and Leonardo da Vinci (1452–1519), the artist philosopher of Florence. In the early part of the sixteenth century the illustrious Copernicus appears (1473–1543). Copernicus, or Copernic, had a keen mind and a firm belief in what may be called the simplicity of nature. On examining the Ptolemaic system he was embarrassed by its epicycles and excentrics, producing, as they did, complexity where he believed there should be simplicity. He, therefore, turned with relief to the ancient ideas of Pythagoras, and of his system he says:

> The several appearances of the heavenly bodies will not only follow from this hypothesis, but it will so connect the order of the planets, their orbits, magnitudes and distances, and even the apparent motion of the fixed stars, that it would be impossible to remove one of these bodies out of its place without disordering the rest and even the whole universe also.

Under the hand of Copernic this system was elaborated and shaped so as to acquire a dignity equal to that of the older system, and, but for the retarding hand of superstition and bigotry, the dawning day might have rapidly advanced.

As it was, Copernic, fearful perhaps of the fate of Roger Bacon, taught in private a few select pupils, and only on his death bed did he see his printed work (1543). Copernic's sudden death was all that saved him from the hands of his enemies. As it was, his book was soon proscribed and his theory placed under the ban of the church.

With the printing of Copernic's work the battle between the *geo-centric* and *helio-centric* hypotheses may be said to have been fairly joined. Copernic himself foresaw the coming conflict. He also saw



THE SOLAR SYSTEM AS CONCEIVED BY COPERNICUS.

that the real conflict would be, not with astronomers, but with churchmen. In the dedication of his book he says:

> If there be some babblers who, ignorant of all mathematics, take upon them to judge of these things, and dare to blame and cavil at my work, because of some passage of Scripture which they have wrested to their own purpose, I regard them not, and will not scruple to hold their judgment in contempt.

Sir Oliver Lodge, in summing up the life-work of this pioneer of science, says:

> We are to remember, then, as the life-work of Copernicus, that he placed the sun in its true place as the center of the solar system, instead of the earth,

that he greatly simplified the theory of planetary motion by this step . . . which he worked out mathematically . . . and, that by means of his simpler theory and more exact planetary tables, he reduced to some sort of order the confused chaos of the Ptolemaic system, whose accumulations of complexity and of outstanding errors threatened to render astronomy impossible by the mere burden of its detail. There are many imperfections in his system, it is true, but his great merit is that he dared to look at the facts of nature with his own eyes unhampered by the prejudice of centuries. A system, venerable with age and supported by great names, was universally believed and had been believed for centuries. To doubt this system, and to seek after another and better one, at a time when all men's minds were governed by tradition and authority, and when to doubt was sin—this required a great mind and a high character. Such a mind and such a character had this monk of Franenburg.

Mr. E. J. C. Morton in a biography of Copernic says:

Kopernicus can not be said to have flooded with light the dark places of nature—in the way that one stupendous mind subsequently did—but still, as we look back through the long vista of the history of science, the dim, Titanic figure of the old monk seems to rear itself out of the dull flats around it, pierces with its head the mists that overshadow them, and catches the first gleam of the rising sun,

"... like some iron peak, by the Creator
Fired with the red glow of the rushing morn."

It is not to be supposed that there were not weighty objections to be urged against the Copernican system. Of these three may be noted:

1. If it be true that the earth moves, why do not the configurations of the stars change with the changing seasons? It is evident that the grouping of the stars depends upon the distance of the earth from them, and if the earth moves the groups of stars in front of the earth's motion should appear to open out while those behind should appear to close up. We now know the correct answer, that is, that the 184 millions of miles making up the diameter of the earth's orbit is lost in the immensity of stellar space and its effect can only be detected by the most refined of modern methods.

2. If the earth moves about the sun, Mercury and Venus should show phases as does the moon.

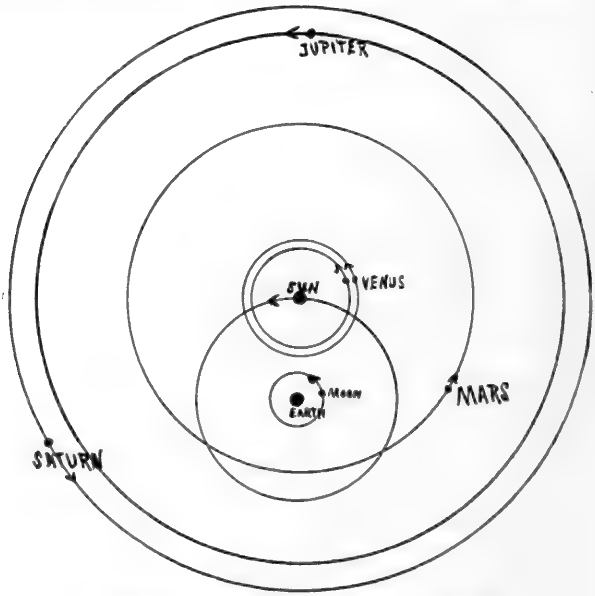
The only answer Copernicus could make was that, were the powers of man's eyesight sufficiently increased, this would doubtless be found to be the case. Seventy years later, Galileo furnished the required proof.

Before looking so far ahead, two important workers must be noted. The first of these is the Danish astronomer, Tycho Brahé (1545–1601), who is well called the father of instrumental astronomy. His aid in the solution of the present problem did not consist in the advocacy of the Copernican system—for he rejected it—but in his patient, faithful gathering of data. His tables of planetary motions and his star tables were the most extensive and the most accurate of his time. Even when

judged by the standards of to-day they are to be viewed with respect. When we remember that the telescope and microscope were then unknown, respect rises to admiration and wonder. So careful was he that not a single mistake due to carelessness has ever been detected in his work.

From 1576 to 1597 Tycho Brahé worked in his well-equipped observatory at Uraniburg on the island of Huen. For twenty years this temple of science was the greatest center of its sort in Europe. Philosophers, statesmen and even kings visited him in his island home. Year by year the great tables of observations grew until further additions seemed but repetitions of oft-told tales. Indeed, the tables grew beyond the ability of their maker to interpret, and some keener mind was needed to unfold their hidden meaning. The possessor of such a mind was even then living in Austria in the person of John Kepler.

John Kepler was born and reared in poverty, and all his life had to struggle to keep actual want from the door. There could scarcely be a greater contrast than that presented by these two men: Brahé, the favored son of fortune, possessing all that wealth and princely favor could procure, acknowledged as the foremost philosopher of his day; Kepler, with nothing to commend him to notice save a passion for knowledge and longing to learn the hidden meaning of equations and formulæ and mystic numbers. The common bond between them was the love of the truth and the capacity for taking infinite pains. For the progress of the race each of these men needed the other, and dame fortune's immediate problem was the bringing them together.



GEOCENTRIC SYSTEM AFTER TYCHO BRAHÉ

By so doing it would be possible for Brahé to pass on to Kepler the completion of his own work, and at the same time train him for an even greater task.

In 1590 James I., of England, visited Denmark and spent eight days with Tycho and his wonderful instruments. On leaving he presented the astronomer with various gifts, and among these was a pet dog of which the astronomer became very fond. Now this canine became the innocent cause of much trouble to his master, for it seems that one day the chancellor of Denmark brutally kicked the poor beast. This was too much for Tycho's temper—never very even—and he roundly berated the chancellor for his cruelty. Of course there is more to the story than just this, but at all events Tycho made a powerful enemy.

KEPLER

who, after the death of the king, stripped the astronomer of all his estates and drove him penniless from the kingdom. For two years he was without a home, but in 1599 found refuge and a pension with Emperor Rudolph II., of Bohemia. Becoming established in Prague, he set up his instruments, and soon students flocked to him again. Among them came the poor youth, Kepler, who soon made himself invaluable to his master. In return, Tycho was kind to Kepler, and together they labored until the former's death in 1601.

With the advent of Kepler (1571–1630) the real problem of gravity together with its solution took definite form. Always a firm believer in the unity and simplicity of the solar system, Kepler rejected the teaching of Tycho Brahé and adopted Copernicus's scheme in toto. Next, he set about bringing order out of the mass of observations accumulated (for the most part) by Brahé. He took infinite pains, testing by actual calculation every hypothesis or rule that he could think of. For example, he tried circular orbits with constant velocities for the planets and the sun at the center. Finding that this did not fit the facts, he placed the sun a little off center and tried again, but the theory did not yet fit the observed facts. "After incredible labor, through innumerable wrong guesses, and six years of almost incessant calculation" the truth began to dawn upon him, until he was able to enunciate three laws which have since gone by his name. The first of these to yield itself to his zeal was the so-called second law which gives the rule governing the velocity of the planet in its orbit.

Law II., *The radius vector sweeps out equal areas in equal times.* Having determined, as he believed, the law of speed, he next inquired into the exact shape of the orbit. Here "however, the geometrical and mathematical difficulties of calculation threatened to become overwhelming," and as the days dragged into months he had every reason to become disheartened. By day he worked, by night he dreamed of his problem, and it is said that the hint which led to its solution came to him as he slept and awoke him. Arising at once, he lighted his lamp and set to work anew at his calculations. Step by step he progressed, and finally, in a paroxysm of delight, he proved what is now known as Kepler's first law.

Law I., *The planets move in ellipses with the sun at one focus.* To these two laws Kepler nine years later in 1618 added a third.

Law III., *The square of the time of revolution of each planet is proportional to the cube of its mean distance from the sun.*

In these three statements Kepler brought order out of chaos and reduced to system a heterogeneous mass of observations and records. When we remember that these laws of Kepler's furnished Newton not only a point of departure, but also gave him a criterion by which to test his results, we begin to see that without Kepler, Newton might not have been possible. Lodge says of him:

> A man of keen imagination, indomitable perseverance and uncompromising love of truth, Kepler overcame ill-health, poverty and misfortune, and placed himself in the very highest rank of scientific men. His laws so extraordinarily discovered introduced order and simplicity into what else would have been a chaos of detailed observations; and they served as a secure basis for the splendid erection made on them by Newton.

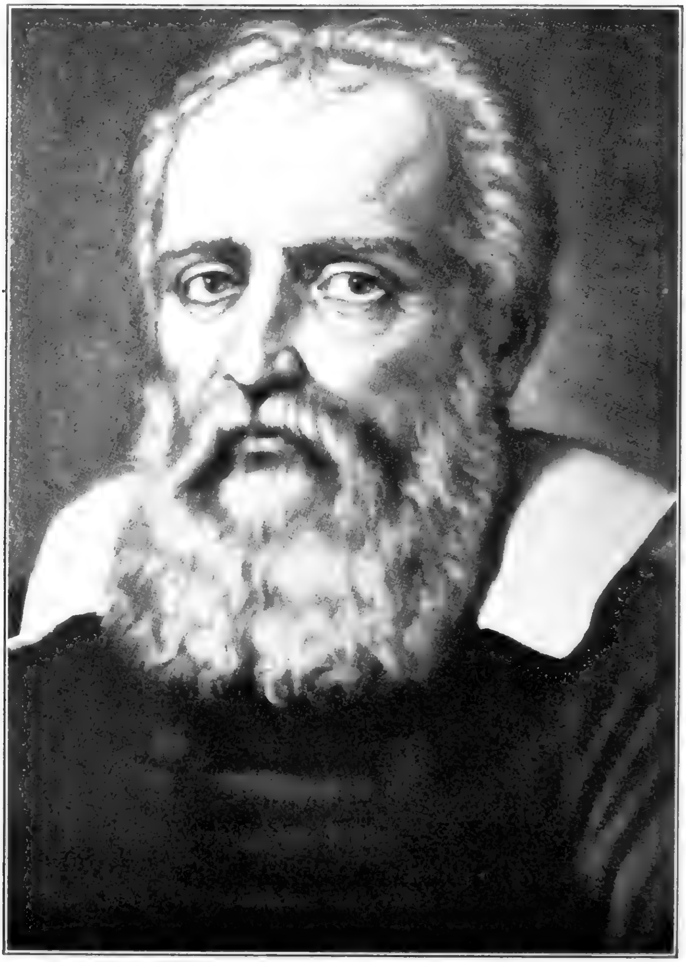
While Kepler was laying the enduring foundations of the Copernican theory, Galileo (1564–1642), was carrying on an open propaganda in Italy. In 1609 he perfected the telescope, and with it, night by night, questioned the heavens. The mountains on the moon, the satellites of Jupiter, sun-spots, the strange appearance of Saturn due to its rings, the changing phases of Venus, were discoveries rapidly announced to an astonished public. Some of the discoveries, such as those relating to Saturn and Venus, were of such an astonishing and revolutionary nature that Galileo first published them in the form of anagrams. The one announcing the phases of Venus, when deciphered, reads as follows: "Cynthiæ Figuras Æmulatur Mater Amorum." Freely translated: "Venus emulates the phases of the moon." The immediate result of Galileo's brilliant work was to convince all unbiased minds of the truth and to array the church in solid phalanx against both him and his system. Of Galileo personally we have not time to speak—suffice it to say that he was made to suffer most cruelly for his beliefs.

In the year he died (1642) was born—on Christmas Day—the man

who was destined to establish forever the truths for which so many had toiled and suffered before him.

We have tried to follow one of the lines of succession leading up to Newton, giving, as it were, his pedigree upon the side of astronomy. It is a noble line: Pythagoras, Eratosthenes, Hipparchus, Ptolemy, Copernicus, Brahé, Kepler, Galileo, with many lesser names unmentioned. There is another line of succession to be traced, and to this I invite your attention for a brief moment—for I have kept you all too long from the main theme of the paper.

In the study of mechanics as in the study of astronomy we must begin with the Greeks. Thus, we find Aristotle attempting to teach the law of falling bodies, and also giving the reason why heavy bodies



GALILEO.

sink while light ones arise. All his statements relating to mechanics are erroneous and some are positively childish.

The first real student of mechanics was Archimedes (287–312 B.C.) To him we owe the foundations of the science. For example, to him we owe the theory of the lever, from which he developed the idea of the center of gravity. He was especially interested in the subject of hydrostatics, and established principles that are of universal application to-day. His practical applications are best illustrated in the engines of war which he devised to aid in the defense of Syracuse. So effective were these that the Romans took the city not by assault but by starvation. For fifteen hundred years thereafter practically no advance was made. In 1452 the Turks took Constantinople, and fugitive Greeks

HUYGENS.

carried Greek manuscripts westward to Europe. These stray documents gave a fresh impetus to science as they did to letters. The first one really to grasp the subject of mechanics and develop it was Galileo (1564–1642). To him we owe the true theory of falling bodies, the law of the pendulum, the theory of projectiles and two of the three great laws of motion, which were put into their final form by Newton himself.

Two stories about Galileo will serve to show what manner of man he was and also to illustrate his methods. In 1583, while worshipping in the cathedral in Pisa, he chanced to notice the swaying of the great chandelier, the lamps of which had been freshly lighted. From watching its stately vibration he fell to timing it, using as a standard his pulse-beat. Thus there dawned upon him one of the laws of the pendulum—that the time of vibration is independent of the arc of motion. How many thousands of times had that same chandelier been observed swinging to and fro, and yet it had awaited the coming of Galileo to read its inner meaning!

On the question of falling bodies Galileo ran counter to Aristotle. That philosopher had taught that bodies in falling acquire velocity in proportion to their weight. Galileo found by a simple but careful study that all bodies acquire the same velocity in falling. With the imprudence of youth he forthwith proclaimed the errors of Aristotle from the house-tops, much to the scandal of his classical friends. In answer to their protests he proposed an experiment, and this experiment was made. The faculty of the University of Pisa together with the interested or curious of the city gathered at the leaning tower—"Pisa's leaning miracle," as Whittier calls it. From the top and at the overhanging side Galileo let fall a one-pound and a one-hundred-pound shot. The two shot started, fell—and struck the ground together. As Lodge exclaims, "The simultaneous clang of those two weights sounded the death-knell of the old system of philosophy and heralded the birth of the new." And yet, it is recorded that while some saw, and were convinced, others—nor is their race extinct to-day—saw, but, consulting their copies of Aristotle, disbelieved.

Following in Galileo's foot-steps—perhaps more cautiously lest he be made to suffer for it—Huygens (1629–1699) further developed and extended the science of mechanics. In particular may be noted his development of the theory of circular motion; the invention, or at least perfection, of the pendulum clock, and the determination of the acceleration of gravity from pendulum observations, a method which is to-day the most accurate one in use. Huygens shares with Galileo all the honors due a scholar and original worker of the first rank. They resemble each other in character, in method and in the great value of their labors.

As bearing upon the law of gravitation the theory of circular motion was of the very greatest value. Without it, Newton must either have failed in his task or have discovered these principles for himself. As a matter of fact he did the latter. Huygens was also the first to grasp the significance of the following occurrence. In 1671 Jean Richter, in the course of astronomical work, carried a pendulum clock from Paris to Cayenne in South America. The clock kept correct time in Paris, but at the latter station it daily fell two and a half minutes behind mean solar time. The pendulum was shortened to correct it, but on returning to Paris it was found to gain time at the same rate that it had before lost it. Huygens at once correctly explained this as due to the rotation of the earth on its axis; thus furnishing the first experimental evidence of the earth's rotation.

The span of Galileo's life was from 1564 to 1642. He died discredited by his church, deprived of his liberty and afflicted with blindness. His enemies thought that they had vanquished him and his ideas. They even attempted to blot out his memory from among men by refusing to allow his grave to be marked. How little they knew! Already through Huygens the new knowledge had made great advances; and in the very year of Galileo's death was born the man whose mighty intellect was to flood with light the dark places of nature and to carry Galileo's work to a proud completion.

The year 1660 was in England an important year for science. This is the year of the founding of the Royal Society, and in the same year Isaac Newton, a young man of eighteen, entered the University of Cambridge from the town of Woolsthorpe in Lincolnshire. In 1663 the society received a royal charter, and some time after King Charles is said to have sent it a weighty problem with which to test its powers. "Why is it," said the king, "that the same fish weighs less when alive and swimming in a pan of water, than when dead and floating on its surface?" There must have been rapid improvement in the caliber of its meetings, for in 1665 its members are listening to Robert Boyle's brilliant papers on the air-pump and the barometer.

In the meantime, Isaac Newton, destined for twenty-five years to be president of the society, was pursuing his studies at Cambridge and in 1665 was given the A.B. degree. This and the following year were the years of the great plague. For a time the Royal Society took refuge in Oxford, while the University at Cambridge was, in the fall of 1666 "sent down," the students and faculty scattering to escape contagion.

Newton returned home, his mind teeming with new ideas and hard problems. He had already mastered the most advanced scientific works of his time—Kepler's "Optics," Descartes's "Analytical Geometry" and Wallis's "Arithmetica Infinitorum." In reading, Newton was in the habit of noting what seemed to him capable of improvement. At this time (1666) he had already projected experiments in optics which were to be the first of his achievements to make him known to the world. In mathematics he had originated the binomial theorem and had laid the foundations of the infinitesimal calculus. Armed with this new weapon of analysis, Newton pushed his mathematical researches in many directions, solving with ease problems that had so far baffled attack. Whatever he touched turned to gold under his hand. So rapidly did his mind work that he seems not to have needed to work out each step in detail; his printed papers sometimes read like a list of answers to difficult propositions. For example, he presents a classification of cubic curves, giving seventy classes in all. Yet in all this list there is no suggestion of the process by which the results were obtained. Among the books that Newton read was Galileo's "Dialogues on Motion," and here as elsewhere he found abundant material for work. In this field of mechanics his mind worked with its usual clearness and rapidity. He restated the laws of motion in such clear and simple terms that for two and a half centuries no word or line has been changed. Bringing to bear his new calculus he readily solved the problem of falling bodies, and in 1666 discovered the laws of circular motion, seven years before they were published by Huygens in 1673.

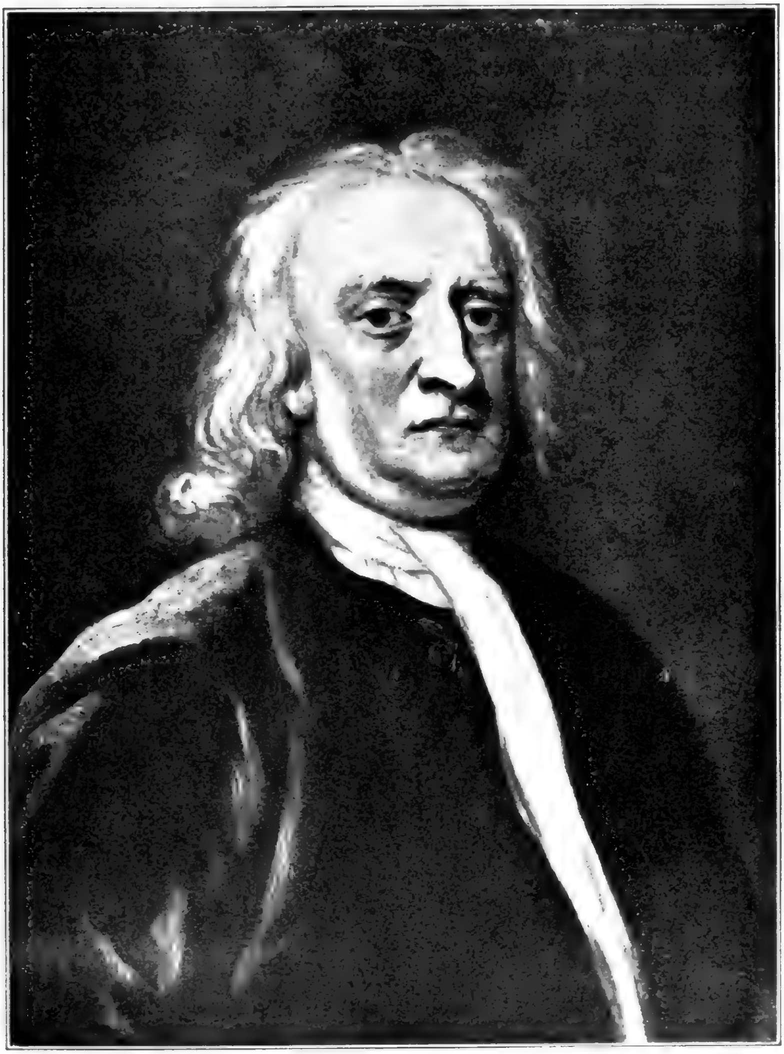
To such a wide reader and deep thinker as Newton, the problem of "gravity" would appeal with keen interest. It would have been but natural that he should have gathered together all that was available of the literature of the subject. Thus he was familiar with Kepler's views expressed in the following citation:

> The true theory of gravity is founded on the following axioms. Gravity is a mutual affection between cognate bodies toward union or conjunction, similar to the magnetic virtue. . . . If the moon and the earth were not retained in their orbits by their animal force or some other equivalent, the earth would mount to the moon by a fifty-fourth part of their distance from each other, and the moon would fall toward the earth through the other fifty-three parts, that is, assuming that the substance of the earth is of the same density. . . . The sphere of the attractive virtue which is in the moon extends to the earth and entices up the waters, but as the moon flies rapidly across the zenith and the waters can not follow so quickly, a flow of the ocean is occasioned toward the westward. If the attractive virtue of the moon extends to the earth, it follows, with greater reason, that the attractive virtue of the earth extends to the moon and much farther, and, in short, nothing which consists of earthy substance, however constituted, although thrown up to any height, can ever escape the powerful operation of this attractive virtue.

Borelli (1608–1679) also expresses views no less explicit, and, in his work, "On the Satellites of Jupiter," distinctly attributes the revolutions of the heavenly bodies to the force of gravity. So also Bullialdus wrote "that all force respecting the sun as its center, and depending upon matter, must be in a reciprocally duplicate ratio of the distance from the center." This last sentence is quoted from one of Newton's letters, and shows how carefully he had read on the subject.

Of Newton's immediate contemporaries, Robert Hooke and Edmund Halley were actively working in this field. Hooke (1635–1702) especially is ambitious to secure the honor of the solution of the problem the answer to which he reads almost exactly right, but the proof of which—poor man—he can not give. Failing in the demonstration himself, he talks on the subject, about the subject, and all over the subject, in the meetings of the Royal Society, in his papers and in his letters. So full of it is he that he imagines that whatever any one else does is stolen from him. Finally Sir Cristopher Wren offers him a prize if in two months he will produce the boasted of solution. None is forthcoming and history must write Hooke down as a most ardent worker and ingenious man, but as totally unequal to the great task imposed upon Newton.

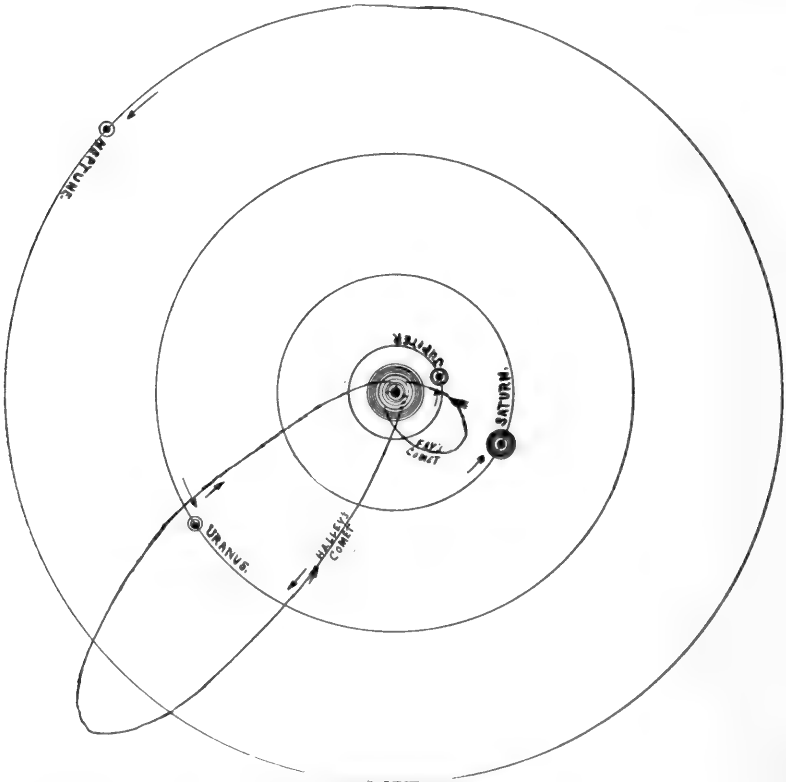
Halley is more modest; he applies the laws of circular motion published by Huygens in 1671, sees clearly that the law of inverse squares



NEWTON.

must hold good, does hold good for the circular orbit; sees also from Kepler's third law that if it can be applied to the elliptical orbit as well then all the planets immediately fall into that celestial harmony predicted by Pythagoras two millenniums before. The law holds for the circle, does it not hold for the ellipse also? We can imagine with what nervous eagerness Halley argues the question with Wren and Hooke and then—Heaven-inspired thought—posts him down to Cambridge to consult Newton. This was in August, 1684.

We must now rapidly review Newton's own work during the twenty years following his graduation from Cambridge in 1665. From the very beginning he was interested in this particular problem of gravity, but it was only one of many. Moreover, his was not a mind to stop short of the full and complete solution. This force of gravity—if it be this force that governs the universe—must be expressed by an exact law; he sees more clearly than any one else what is involved. So he ponders over the problem, and one day—would that we knew the date—he is seated in his garden studying, beside him his books and papers. In the sky is the pale moon and as Newton gazes upon her he ponders



SOLAR SYSTEM AFTER NEWTON.

on the world-old problem, this riddle of the ages. What force holds that moon forever circling about the earth? An apple falls to the ground beside him and its thud awakens a train of thought in his mind. Can it be the same force in the two cases—is the moon but a larger apple forever falling toward the earth, urged by the force of gravity, and forever receding from the earth, urged by her own uniform motion? Fascinated by the thought, Newton sets to calculating. He has studied out the laws of uniform motion and of accelerated motion—now he combines the two and gets the law of circular motion. He draws a circle to represent the moon's orbit and calculates by what amount the moon ought to fall toward the earth in a minute, assuming that its distance from the earth is that given in the books. In his own words he finds the figures "to answer pretty nearly." But this does not satisfy him; to a mind like Newton's "pretty nearly" is as bad as "not at all," so he lays aside his papers until more exact data are at hand. He has, however, made the first stage of the journey toward the goal. This was in the plague year, 1666. As soon as the university is again convened, Newton returns to Cambridge and for a number of years is engrossed in the study of optics. In 1672 he is momentarily reminded of the problem while editing a revised edition of Varenius's "Geography." In this he gives the accepted value for the earth's degree sixty-one and one half miles. This was probably the value Newton used in his calculations of 1666 and which fitted "pretty well," as he said. In 1679–80 Newton has an unwilling and one-sided correspondence with Hooke relating to the theory of projectiles, and in which the subject of gravity is involved.

We may be sure that during these years Newton had many times analyzed the grand problem of solar gravity and had carefully noted just what was involved therein. We may even venture to note what must have been his thoughts. If, he would say to himself, it be gravity that rules the motion of the moon, then I must prove the following:

1. Gravity must act on all kinds of matter alike, for the earth is a composite body, and presumably the moon also.

2. We know with a fair degree of accuracy that the moon is sixty-one earth-radii from us, but to make any calculation, this distance must be known in feet. Hence it is important that measurements of the size of the earth be made with the greatest care.

3. The same law should extend to the planets also, but the planetary orbits are ellipses, hence I must prove that the ellipse is a possible or necessary orbit under such a law of force.

4. I must determine some point from which measurements of distance between earth and moon are to be made, *e. g.*, shall it be from the centers of these bodies? Also, does the same law of force hold good over the whole distance, or is it modified as the surface of the earth or moon is approached?

Whether or no Newton set the matter in orderly array, it is clear from his papers and letters that each of these points was considered. Thus he proves the first point by an exhaustive series of experiments on pendulums in which he varies the material of which the pendulum is made, proving clearly, "by experiments made with the greatest accuracy, the quantity of matter in bodies to be proportional to their weights." The converse must also be true—the weight or pull of gravity on bodies is proportional to their mass or quantity of matter.[1] The second point Newton did not himself attack, but in 1682, when attending a meeting of the Royal Society in London, he heard of Picard's recent measurements of the earth's degree. On returning to Cambridge he inserted the new value in his old calculations of 1665, measuring the distance from earth center to moon center. Finding as he advanced that the result was manifestly going to produce the long-wished-for answer, he found it impossible—so the story goes—to proceed. With the aid of a friend the calculation was completed, and Newton had reached another milestone on the way towards his cherished goal. The figures tally exactly—has he not solved the problem and may he not proclaim the answer to a waiting world? None but Newton knew the distance yet to be traveled before complete success should be his. Nothing short of this could satisfy his truth-loving mind, and the world must wait. The third point may be stated thus: "Given a central force varying as the inverse square of the distance, show that the orbit is an ellipse with the force-center at one focus." This Newton did before the year 1684, for in August of this year, when Halley, disgusted with Hooke's bombast, came to Cambridge, he asked Newton without delay the following question: "What path will a body describe if it be attracted by a center with a force varying as the inverse square of the distance?" To this Newton at once replied, "An ellipse with the center of force at one focus." "How on earth do you know?" exclaimed Halley in amazement and delight. "Why, I have calculated it," and Newton rummaged for the paper. Failing to find it, he promised to forward it to Halley by post. This promise Newton fulfilled in November. It is not known how much ground was covered in this paper, but, of course, the desired demonstration of the third point above noted was given. Newton must now have realized that he must solve the fourth point and thus complete the work so nearly finished. Something of this may have been expressed in his letters to Halley, for in December, 1684, Halley again visited him and urged him to continue his investigations. Thus far he had shown that Kepler's laws called for the inverse square law of gravity—that Picard's value of the earth's radius fitted exactly into the theory. It but remained to prove that he is correct in taking the distance from center to center of the earth and moon. For weeks and months he works over this proof and finally, some time in 1685, it yields to his unremitting toil. The approximate date of the achievement we know from a letter of Newton's to Halley dated June 26, 1686, in which he says, "I never extended the duplicate proportion lower than to the superfices of the earth, and before a certain demonstration I found the last year, have suspected it not to reach accurately enough down so low." The answer, mathematically proved in Prop. LXXIV. of Book I. of the "Principia,"

[1] "Principia," Book II., Prop. XXIV., Theorem XIX.

is that a sphere attracts all outside bodies as if its mass were concentrated at its center.

Thus he reached his goal at last, and after twenty years of work, ranging over many subjects, the key of the universe lies in Newton's hand. Surely, now, he will publish it and proclaim its discovery to the world. Not so; he must first have the joy of undisturbed possession. Also there is much more to be done. The law he has proved is an "open sesame" to wider knowledge. Or, to change the figure, it is as if a mountain climber, who has toiled upward and upward, now stands at last on the topmost height. As he is climbing he thinks that if he can but gain the summit it will be enough—he will be content and rest. The toiling climber does not realize what awaits him at the top, until the whole panorama of plain and mountain, of crag and canyon, bursts upon his astonished sight. With this before him he forgets his toil, forgets to rest and devours the view. So with Newton, having at last mastered the central law upon which the universe swings, he saw the members of the solar system sweeping in orderly grandure through space, he saw this law governing every motion of every satellite and comet, accounting for the nutations and perturbations, which before seemed to make order impossible. He saw it causing the tides with the rising and setting of the sun and moon. All this and more he saw, and we can not wonder that instead of rushing into print, he shut himself up and worked and thought and wrote, and calculated and worked and thought and wrote.

For two years he labored, sleeping little, eating little, always lost in thought. Often, it is said, on rising, he would sit for hours half dressed upon his bedside. Often for days, he would seem oblivious to all external events. The following story well illustrates his abstraction. One day a friend, Dr. Stukely, called and found Newton's solitary dinner ready on the table. After waiting a long while, Dr. Stukely thought to play a joke on Newton, which he proceeded to do by eating his dinner for him. Having done so, he rearranged the table, covering the dishes so that it would not appear that anything had happened. At length Newton appeared, and, after greeting his friend, sat down to dinner, but, on lifting the cover, said in surprise, "Dear me! I thought I had not dined, but I see I have."

So it went on for two full years, until Newton felt that his work was done. He divided it into three books. The first is entitled The Mathematical Principles of Natural Philosophy, and comprises about two hundred and fifty pages. It reminds one of a geometry, with its propositions, theorems, scholiums and problems. The first book is divided into fourteen sections and contains ninety-seven propositions, fifty theorems and forty-seven problems. Book II. discusses The Motions of Bodies. Here are found fifty-three propositions, forty-one theorems and twelve problems. Book III. has fewer diagrams, less mathematics and more discussion. The principles of natural philosophy are applied to the explanation of the solar system, and such topics as comets and tides are carefully treated. There are forty-two propositions, twenty-two problems and twenty theorems. The whole work covers 507 printed pages, and has a total of 192 propositions, 113 problems and 79 theorems, besides lemmas and scholiums in abundance.

Oliver Lodge in an outline of the "Principia" selects seventeen points for special emphasis. Of these a few may be reviewed.

1. Newton shows from Kepler's laws the following: (*a*) From the first law, that the law of gravity is inversely as the square of the distance. (*b*) From the second law, that this force is directed toward the sun as center. (*c*) From the third law, that all the planets are acted on by the same law of gravity; *i. e.*, that the law of gravity extends to the uttermost confines of the solar system.

2. From the length of the year and the distance of any planet from the sun Newton calculates the planet's mass, using the earth's mass as a unit.

3. He recognized the comets as members of the solar family and showed how to calculate their orbits.[2]

4. He showed that the earth, as a result of its rotation, must be flattened at the poles, and calculated the amount (28 miles).

5. He laid the foundation for a complete theory of the tides.

We have but noted the high lights, as it were, of Newton's work. No wonder that he became lost to external events as his mind grappled with problem after problem, and one by one lay bare the secrets of the universe. As an example of the style in which the "Principia" is written, we may quote from the beginning of the third book where he lays down rules for reasoning in philosophy:

> *Rule I.* We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances. To this purpose the philosophers say that nature is pleased with simplicity and affects not the pomp of superfluous causes.

The "Principia" was finished in the spring of 1686. It was published by order of the Royal Society, being issued from the press in July, 1687. Newton, from being a little-known member of the faculty of Cambridge, was at once recognized as the foremost scientist of the world. Honors were showered upon him. He was sent to parliament. He was elected president of the Royal Society. The queen made him a knight of the realm. He was given a lucrative position under government and moved to London. His work for science was finished, and for forty years he reaped the reward of his labors.

[2] The first cometary orbit to be calculated was done by Halley upon the comet bearing his name, which last year made its third return since Newton's day.

What Newton accomplished in optics and in mathematics would entitle him to high rank in the world of science. Of his work in mathematics the German scholar, Leibnitz, said, "Taking mathematics from the beginning of the world to the time when Newton lived, what he had done was much the better half."

The work included in the "Principia" was most of it done between 1680 and 1686. By far the greater part was done during the last two years of this short period, or between the forty-second and forty-fourth years of his age. This work, in its scope, in its far-reaching importance, and in the order of mind required for its accomplishment, raises Newton not merely to the first rank of the world's great minds, but compels the world to admit no second in his class. His genius shone resplendent even in his own day. We have already quoted Leibnitz. A French admirer wrote to an English correspondent, "Does Mr. Newton eat, drink, sleep like other men? I picture him to myself as a celestial genius, entirely removed from the restrictions of ordinary matter." Says Lagrange (1736–1813), a great French mathematician, "Newton was the greatest genius that ever existed, and the most fortunate, for we can not find more than once a system of the world to establish." The English writer, Whewell (1794–1866), writes, "The (Law of Gravitation) is indisputably and incomparably the greatest scientific discovery ever made, whether we look at the advance which it involved, the extent of truth disclosed, or the fundamental and satisfactory nature of this truth." Pope in a striking epigram expresses the same thought:

> Nature and Nature's laws lay hid in night;
> God said, Let Newton be, and all was light.

La Place, who did much work along the lines laid down by Newton, says of the "Principia": "The universality and generality of the discoveries it contains, the number of profound and original views respecting the system of the universe it presents, and all presented with so much elegance, will insure to it a lasting preeminence over all other productions of the human mind."

Sir Oliver Lodge says of Newton: "In science the impression he makes upon me is only expressed by the words 'inspired,' 'superhuman.'"

Of his own work Newton says: "I know not what the world will think of my labors, but to myself it seems that I have been but as a child playing on the seashore; now finding some pebble rather more polished, and now some shell rather more agreeably variegated than another, while the immense ocean of truth extended itself unexplored before me." When asked how he made his discoveries, he replied: "By always thinking unto them. I keep the subject constantly before me, and wait till the first dawnings open slowly by little and little into a full and clear light." Commenting upon this somewhat modest remark Lodge says: "That is the way—quiet, steady, continuous thinking, uninterrupted and unharassed brooding. Much may be done under these conditions; much ought to be sacrificed to obtain these conditions. All the best thinking work of the world has been thus done."

In closing, let us pause and consider the state of knowledge before and after Newton. Before him are the foreshadowings of Copernicus, the dim gropings of Kepler, the elementary truths of Galileo, the flashes of Borelli and Huygens, the fantastic speculations of Descartes; after him is a magnificent and comprehensive system of well-ordered knowledge. As we contemplate this we can understand the significance of the inscription on Newton's tomb. "Let mortals congratulate themselves that so great an ornament of the human race has existed."

EDWARD PALMER[1]

BY WILLIAM EDWIN SAFFORD

Than longen folk to gon on pilgrimages,
And *palmers* for to seken straunge strondes.
Chaucer, Gen. Prol. to Canterbury Tales.

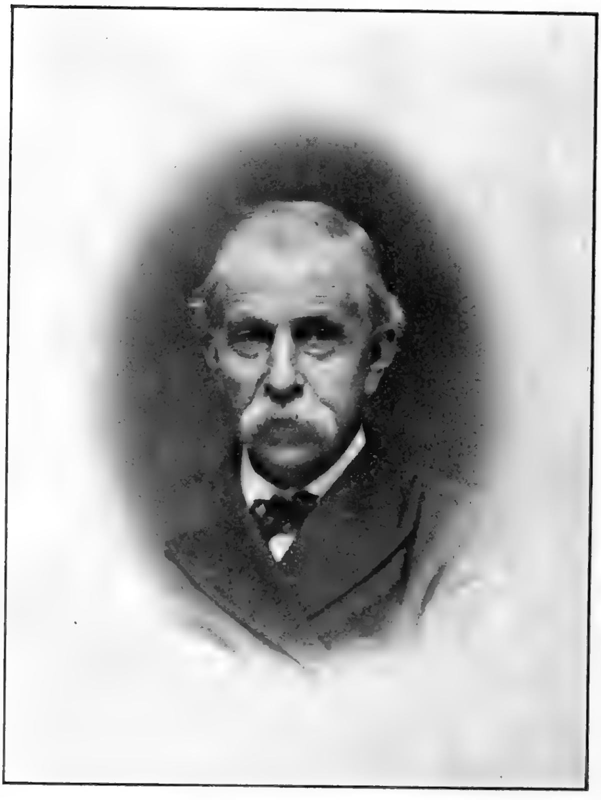
EDWARD PALMER is a man well named. A palmer of the olden time was one who had traveled to the Holy Land in fulfilment of a vow, and brought back with him a palm branch to be placed on the altar of his parish church. Afterwards the name was applied to pilgrims who traveled unceasingly from land to land, under a perpetual vow of poverty and celibacy.

This is what our Palmer has done. From the age of early manhood until now, the winter of his life, never content to remain inactive even for a short period, he has set out upon one pilgrimage after another, bringing back many palm branches and other strange and beautiful products of distant climes, reverently to lay them on the altar of science.

He is an Englishman by birth, born January 12, 1821, at Hockwold cum Wilton, near Brandon, in the county of Norfolk. His father was a professional florist and horticulturist; so that from his earliest childhood his associations have been with flowers and shrubs and trees. When a youth of eighteen he came to America and settled at Cleveland, Ohio. There it was his privilege to meet with Dr. Jared O. Kirtland, one of the most eminent and respected scientific men of his day, in whom there was combined a peculiar personal charm and magnetism with great zeal for the study of nature.

Dr. Kirtland was not only an accomplished botanist, but a practical horticulturist as well, and a man whose greatest pleasure it was to gather young people about him and instill into them a love for natural history. He was one of the earliest members of the American Academy of Sciences, and in connection with the Geological Survey of Ohio made extensive collections of plants and animals of that state. This kind and learned man found a willing disciple in young Palmer, whom he invited to his home and, inspiring him with the display of his zoological collections and herbarium, taught him to prepare bird skins and to dry and press plants, thus laying the foundation for his future career.

[1] A biographical sketch read at a meeting of the Botanical Society of Washington, D. C., on the occasion of the eightieth anniversary of Dr. Palmer's birth.



Yours Sincerely
Edward Palmer

While in Cleveland Edward Palmer made his home with Hon. John W. Taylor, formerly speaker of the House of Representatives, a man of national reputation, who after a long and active life had become a helpless paralytic and was living in that city with a married daughter. Mr. Taylor was visited by many eminent men, and young Palmer was present at many interesting discussions of current events.

At that time there was much talk of opening Paraguay, the hermit nation of South America, to the outside world. It had not been long since Commodore Perry had knocked at the door of Japan and gained entrance; and the scientific results of the United States Exploring Expedition, which appeared in print from time to time, were frequent topics of conversation. When the United States government decided to send an expedition to Paraguay, young Palmer applied for a position as collector of natural history specimens. A small vessel, the *Water Witch,* commanded by Thomas Jefferson Page, was fitted out for the purpose, and Edward Palmer's name was entered upon its rolls.

His duties at sea were to assist the ship's surgeon in caring for the sick and administering medicines. He was placed in charge of the ship's dispensary and was assigned to various stations at drills and quarters. On arriving in South America he was to collect and prepare specimens of birds, reptiles, mammals and plants, as well as objects of ethnological interest.

The *Water Witch* left the United States in February, 1853, reached the mouth of the Rio de la Plata without accident, and after a short stay at Buenos Ayres proceeded to Asunción, the capital of Paraguay. She then steamed up the river beyond into the territory of Brazil, where much interesting information and material were collected. A history of this memorable expedition and of the war with Paraguay which resulted may be found in Captain Page's work on La Plata.[2] Dr. Palmer's personal notes contain much of vivid interest, and I regret that there is not space in the present paper to give them in detail. It is sufficient to say that he was called upon not only to superintend the delivery of ammunition from the magazine of the vessel, but also to dress gunshot wounds and to attend to the burial of the dead.

No account of the scientific results of the expedition was published. There was no one at the time to identify and describe the plants collected, which for a time were lost; and we come upon them now and then in the collections of the national herbarium, many of them still unnamed.

One of the most interesting episodes of the *Water Witch* Expedition was the meeting of an officer sent from the ship on a reconnaissance with Bonpland, the companion of Humboldt on his travels in America.

[2] Page, Thomas Jefferson, "La Plata, the Argentine Confederation and Paraguay," New York, 1859.

This venerable naturalist had for many years been a prisoner of the Paraguayans, but he was now living like a patriarch on his own plantation, surrounded by a brood of sons and daughters and cared for by a devoted native wife.

On his return to the United States Edward Palmer first went to Cleveland to give his friends an account of his wanderings, and then to England to visit the home of his childhood, as well as the great World's Fair at the Crystal Palace. Coming back to America, he took a course of medical instruction, to supplement as well as possible the practical knowledge he had acquired on the *Water Witch*. He then received an appointment as collector in connection with the Geological Survey of California, working under the direction of Dr. Cooper, especially on the marine invertebrates of the California seacoast. He was thus engaged when the civil war broke out.

In 1862, when President Lincoln called for troops, Palmer returned east and applied for a position as acting assistant surgeon in the army, relying on his past experience as a voucher for his fitness for the work. He accompanied Colonel Leavenworth to Colorado, under the promise of an appointment, but for many months he served without appointment or pay in caring for sick soldiers at various posts. At Fort Lyon there was much sickness among the troops, and he was ordered to relieve the contract surgeon at that post. From this time until the close of the war he was engaged at various posts, often riding with the sick in ambulances, but not resisting the temptation en route to alight and gather up plants, reptiles and other objects which seemed to him of interest; for he was a born collector. One of his last stations was Kansas City, where he assisted the surgeon in the city hospital.

After the close of the war he was stationed at various posts in Arizona and the Indian Territory, where his work of attending the sick was pleasantly varied with his occupation as a collector, sometimes receiving scant sympathy from his commanding officers, sometimes encouraged by them to pursue his work in the cause of science; but always on his detachment from a post carrying with him testimonials as to the faithful performance of his duties, his tender care of the sick, and his remarkable success in using simple herbs and local remedies when his official supply of medicines was exhausted. His personal notes teem with interesting anecdotes, such as an account of a scouting expedition against the Apaches, on which he collected ethnological material while half-breed soldiers were bayonetting and scalping hostile Indians; and the story of his vicissitudes during an epidemic of sickness at Fort Grant, when he himself was stricken. He did not on that account cease to add to his collection, but while he lay in the little hut that served as his dispensary he was aided by a cat that brought in small animals to her kittens. He would seize her gently, take away her prey, and after removing the skull and skin of the animal, allow her to proceed with its body to her little ones. In this way he secured specimens of several new rodents. He also gives an interesting account of a raid by a party of Indians in the Indian Territory, who were about to destroy his collections, but stopped short at the sight of snake-skins, evidently recognizing them as the property of a medicine man with whom it was dangerous to trifle.

Dr. Palmer's reputation as a collector having been established, he was sent by the commissioner of agriculture, in March, 1869, on a mission to New Mexico and Arizona, to report on the agricultural resources, the commercial products, the climate and fertility of the soil, and the general habitable features of the various localities to be visited by him.

He proceeded to Fort Wingate, N. M., and across the border to Fort Defiance, Ariz., whence he visited the Navajo Indians and the Hopis, or Moquis, of northeastern Arizona. Dr. Palmer in his notes describes the agriculture of the Hopis and gives an account of a feast at which the principal articles of food were thin, scroll-like cakes of blue corn-bread, which were used by the Indians for plates and spoons as well as for food; syrup made from the roasted crowns of an agave; peaches, which the Indians had begun to cultivate; and mutton from their flocks. At the village of Oraibi a rabbit hunt was organized in honor of his visit, and Dr. Palmer for the first time saw boomerangs used as weapons of the chase. Specimens of these were secured for the National Museum. Some of the cactaceæ collected in this region were described by Engelmann, and by Coulter in Vol. 3 of the Contributions from the U. S. National Herbarium.

After his return to Fort Wingate, Dr. Palmer was furnished with an army escort for his journey to Fort Whipple, Ariz. On his way thither he stopped to collect on the slope of San Francisco Mountain, a locality which had never before been visited by a botanist. From Fort Whipple he made various excursions to neighboring localities, securing much botanical material and objects of ethnological interest illustrating the habits and customs of the various tribes of Indians inhabiting the territory of Arizona. This was forwarded to San Francisco, by way of the Colorado River and the Gulf of California. It was shipped at San Francisco on the *Golden City* to go to New York by way of the Isthmus of Panama; but the vessel was lost, with everything on board. Only a collector can realize what a blow this was to Dr. Palmer. "When I heard of the disaster," said he, "every hardship and risk I had endured came to my mind; one by one I recalled some special object of beauty or of interest which I felt I could never replace."

From Arizona he entered the Mexican state of Sonora and proceeded southward to Guaymas, collecting on the way. After visiting the

Yaqui Indians in the interior, he crossed the Gulf of California to the peninsula of Lower California and went thence by sea to San Francisco. Among the plants collected in northern Sonora and along the shores of the Yaqui River, many proved to be species hitherto unknown. One of them, a columnar cactus, had fruit densely covered with spines, which was used by the Indians for brushing their hair. This was named *Cereus pecten-aboriginum* by Engelmann, and afterwards described by Sereno Watson in Volume 21 of the *Proceedings of the American Academy*.

Dr. Palmer next went to Utah. He carried with him a letter of introduction to Brigham Young, who assisted him most willingly in his work by giving him letters to the authorities in the southern part of the territory. His work was chiefly in the vicinity of St. George, in the southwest corner of the territory. This region, considerably lower than the great Utah basin, is remarkable for its semitropical products, such as pomegranates, cotton, etc., on which account it is sometimes called *Dixie Land*. From St. George he made a long and painful journey across what is now the southern corner of Nevada to Hardyville and Camp Mohave, on the Colorado River, and thence across southern California to San Francisco.

On his return to Washington, in November, 1870, he received a letter from Dr. Torrey, congratulating him on the successful accomplishment of his mission. "I had anticipated much pleasure," Dr. Torrey wrote, "in spending several days with you at the agricultural department, and in hearing from you an account of your doings and adventures.

"You have, in the last few years, done great service to North American botany, and I trust that we shall receive yet greater benefit from your explorations. There are many choice plants to be found in our little-explored states and territories.

"I should be delighted to look over your late discoveries, and I hope you will be able to spare me duplicates. It is of great importance that the herbarium of Columbia College should be as complete as possible in North American plants."

The commissioner of agriculture, Horace Capron, in his report for 1870, calls special attention to the collections of Dr. Palmer and states that the botanical material accumulated by him "is now in process of elaboration by the distinguished American botanists, Drs. Gray, Torrey and Engelmann, and includes a considerable number of plants new to science which will be greatly prized by scientific botanists, and eagerly sought by botanical institutions at home and abroad."

"The design of establishing at the seat of government a collection of plants worthy of the name of a national herbarium is thus in process of rapid accomplishment, at a comparatively small cost; and it is confidently expected that this collection, now probably the third in point of size, will eventually exceed all others in the amount and value of its materials for illustrating North American botany."[3]

In the same report was published a paper on the "Food Products of the North American Indians," based upon Dr. Palmer's field notes and observations.

During the next two years Dr. Palmer was engaged in making collections of marine invertebrates and algæ on the New England coast, and in going over his material at the Museum of Comparative Zoology at Cambridge.

From Cambridge, at the suggestion of Professor Gray, Dr. Palmer made a trip to Florida and the Bahama Islands. A list of the algæ collected by him at this time was published by Professor Daniel Cady Eaton, of Yale, but no list of the flowering plants was published. One of the most interesting plants found by him in Florida was a yellow waterlily, *Nymphæa flava,* which had been figured many years before by Audubon, but which had remained unknown except through Audubon's figure until its rediscovery by Palmer. In Audubon's figure the leaves of a *Nuphar* instead of those of a *Nymphæa* had been depicted, and Dr. Palmer's specimens were the first to establish the true nature of the plant.[4]

In 1875 Dr. Palmer visited Guadalupe, an island lying some distance off the coast of Lower California, which had never before been visited by a botanist. His collections on this island revealed a fauna and flora of peculiar interest, connecting it rather with upper California than with the adjacent peninsula. Every bird in his collection except a single sea bird proved to be new to science, though represented by allied forms on the mainland; and among the plants there were twenty-one new species, the greater part of which proved to be peculiar to the island. The account of Dr. Palmer's personal experiences on the island is most interesting, but unfortunately there is not space here to repeat it.

While on the island he lived in a dug-out with a roof of poles covered with dirt. His explorations were attended with much difficulty and for several weeks he was seriously ill. Sometimes in order to secure plants growing on the faces of cliffs, which had been preserved on account of their inaccessible position from the greed of goats, he made use of a noose at the end of a long pole, much to the amusement of the herders, who laughed at the doctor's attempts to "lasoo plants." Many of the species could have been secured in no other way. "Goats," he says, "were my only rivals; but they made a clean sweep of everything in reach, not discriminating between what was common and what was rare."

[3] Report of the Commissioner of Agriculture for 1870, pp. 11, 12, 1871.

[4] See *Am. Journ. Science*, No. 65, 416, 1876.

An account of the vegetation of the island based upon his collection was published by Sereno Watson in Volume 11 of the *Proceedings of the American Academy,* 1876; and a description of the birds by Robert Ridgway in a bulletin of the Hayden Survey.[5]

Immediately after his return from Guadalupe Island Dr. Palmer began to collect botanical and ethnological material in southern California for the approaching Centennial Exposition at Philadelphia. It was at this time that he crossed the boundary line into Mexican territory and made his famous collection of plants in the great canyon of the Cantillas Mountains, in the northern part of Lower California, a locality never before visited by a botanist, which yielded a number of new and interesting species. The collections were of special importance, and added much to the knowledge of the botany of the region. Many of Dr. Palmer's notes were embodied by Gray and Watson in their "Botany of California," which was then in preparation. He also visited the Diegueño Indians of southern California and obtained valuable material illustrating their arts and habits of life; their weapons, baskets, pottery, foods and medicines.

On one of his collecting expeditions near the Lower California boundary line he came upon a party of almost naked Cocopa Indians gathering their annual supply of pine nuts, the fruit of *Pinus quadrifolia.*

"It was an interesting sight," said he, "to see these children of nature with their dirty laughing faces, parching and eating the pine nuts. They had already filled many bags and were eating them by the handful. Indeed we found the piñones to be rich and well-flavored, and we were not satisfied with few. We realized that these happy free people were in their natural habitat here beneath the pines. At last we had the privilege of seeing primitive Americans gathering their uncultivated crop from primæval groves."

Another plant collected by Dr. Palmer proved to be the type of a new genus, which Professor Gray named *Palmerella* in his honor, stating that he did so in acknowledgment of Dr. Palmer's "indefatigable and fruitful explorations of the botany of the southwestern frontiers of the United States, from Arizona to the islands off Lower California, in which region he has accomplished more than all his predecessors."

Dr. Palmer sent a fine collection of woods to Dr. Vasey, who was preparing an exhibit of forest trees of America for the Centennial Exposition.

[5] Ridgway, Robert, "Ornithology of Guadalupe Island, Based on the Notes and Collections made by Dr. Edward Palmer," Bull. Hayden Survey, No. 2, p. 183, 1876. See also by the same author, "The Birds of Guadalupe Island, Discussed with Reference to the Present Genesis of Species," *Bull. Nuttall Ornitholog. Club,* Vol. 2, p. 58, 1877.

The months of November and December, 1875, were spent in southwestern Utah, where he made a collection of the principal plants and the plant products of the Paiutes. An account by Dr. Palmer of "Indian Food Customs" was afterwards published in Volume 12 of the *American Naturalist,* and reprinted in the *American Journal of Pharmacy* in 1878. Several burial mounds in the vicinity were opened by Dr. Palmer, and a valuable collection of pottery, beads, etc., resembling similar objects of Pima and Hopi Indians of Arizona, was made and sent to the National Museum.

From St. George, Utah, Dr. Palmer went to San Bernardino, California, for necessary supplies, and then back to Arizona, where he visited the Mohave Indians of the Colorado River, concerning whose arts and customs he obtained valuable notes, describing their methods of fishing, trapping, pottery-making, food preparing, their navigation on balsas made of bundles of reeds and their primitive methods of agriculture. He also collected a number of living cactaceæ characteristic of the vegetation of the region, including the giant *Cereus,* for exhibition at Philadelphia.

From Camp Mohave he crossed the desert to San Bernardino, discovering on the way a beautiful little plant which proved to be the type of a new genus of the poppy family, and to which Professor Gray gave the name *Canbya.*

On May 29, accompanied by Dr. Parry, Professor Lemmon and Mr. Craft, of Crafton, and several others, Dr. Palmer set out to climb Mount San Bernardino. The next day Dr. Palmer fell from his horse and severely injured his spine. He was obliged to lie until the following day on an improvised bed, when he was carried to the bottom of the mountain to a carriage in which Dr. and Mrs. Parry had come to take him home. In the meantime an account of the expedition had been published at San Bernardino, in which it was stated that the doctor had been left "on the mountain *without grass or water,* with a man to look after him." "Wherever I went for some time afterward," said Dr. Palmer, "I was pointed out as the man who had been left on Grayback Mountain without grass or water; sometimes I was jocosely addressed: 'Hello, old grass-and-water, how's your back?'"

Dr. Palmer next visited the region surrounding San Luis Obispo, California, where he secured several new species, and thence he returned with Dr. Parry and Mrs. Parry to their home in Davenport, Iowa.

In December, 1876, he returned once more to the vicinity of St. George, Utah, this time for the purpose of making archeological explorations for the Peabody Museum of Harvard University. Accounts of the discovery of remarkable tablets bearing signs of the zodiac, conventional figures of the planets, etc., had been recently published, and they were given serious consideration by many archeologists of good standing. Dr. Palmer's researches, however, proved that the remains of ancient occupation of the region were in no way distinguishable from those of similar character in Arizona and New Mexico. The plates were undoubted forgeries.

In addition to his archeological explorations he assisted Dr. Parry, who accompanied him, in completing a collection of the spring-flowering plants of the region.

It was now decided to invade Mexico in prosecution of botanical and ethnological work, and plans were formulated by which Dr. Palmer and Dr. Parry were to go together. The expenses were to be borne by several institutions as well as by individual botanists, who were to receive sets of plants. The two collectors accordingly proceeded to the city of San Luis Potosi, going by sea to Veracruz, and thence by rail to the City of Mexico. After visiting the National Museum in that city they turned northward, Dr. Palmer stopping on the way at the city of Zacatecas and at Aguascalientes.

After making extensive collections in the mountains of San Luis Potoso, Dr. Parry fell ill and was obliged to return home. Dr. Palmer continued the work, and after collecting on the tableland and mountains, returned by way of Tampico, descending into the more tropical lowlands near the gulf coast, and greatly supplementing the collections made in the higher altitudes.

Sets of plants were sent to the various subscribers to the expedition, but the most complete set was sent by Dr. Parry to the Kew Herbarium, which caused not a little dissatisfaction among some of the American subscribers. The results of the expedition were for the most part embodied in the great work by Hemsley, the "Botany of the Biologia Centrali-Americana."

The latter part of the following year, 1879, Dr. Palmer made extensive collections in western Texas, and in 1880 he returned to Mexico to supplement his previous collections, exploring chiefly certain localities in the states of Coahuila, Nuevo Leon and a part of San Luis Potosi. He sent a nearly complete set of the plants collected at this time to Kew, and they too were included by Hemsley in the "Biologia." A more complete set went to the herbarium at Cambridge, Mass., and were the basis of two papers published by Sereno Watson, in Volumes 17 and 18 of the *Proceedings of the American Academy,* in which a complete list of the plants collected by Parry and Palmer in 1878 and by Palmer in 1879 and 1880 was given.

The archeologists at Cambridge and in the Bureau of Ethnology becoming interested in the relationship between the aboriginal inhabitants of the tablelands of Mexico and of the great region of the Mississippi Valley, Dr. Palmer was engaged to make researches. Accordingly from 1881 to 1884 he was almost continuously at work opening prehistoric mounds and graves in the states of Tennessee, Arkansas, Indiana, North Carolina, Georgia and Alabama.

In the latter part of 1885 he was sent to southern Florida to make a collection of corals, echinoderms, mollusca and other invertebrates for the approaching exposition at New Orleans. He gathered a wealth of valuable material, which, after the closing of the Exposition, became the property of the United States National Museum.

He was sent once more to the southwestern region of the United States, where he made a very complete collection of material illustrating the arts of the Cocopa, Pima and Yuma Indians. Much of his material was of an ethno-botanic nature, including a long list of food-plants, medicinal plants, fiber plants, etc., of the Indians, together with notes on the methods of cooking, brewing, extracting fibers, basket-making and the like.

Much pleased with Dr. Palmer's success, Professor Baird, director of the U. S. National Museum, decided to send him to the mountains of southwestern Chihuahua, a part of the western Sierra Madre of Mexico, for the purpose of studying the Tarahumara Indians of that region, an interesting tribe inhabiting caves and dwellings of the most primitive kinds; with the object of comparing them with the Cliff Dwellers of Arizona and New Mexico. Letters were sent to Governor Alexander R. Shepherd, then vice-president and general manager of the Silver Mining Company at Batopilas, informing him of Dr. Palmer's purposed visit, and asking such assistance as Governor Shepherd might be willing to give him in the prosecution of his work. Professor Baird's request met with a cordial and prompt response from Governor Shepherd, who did everything in his power to aid him.

Much botanical work was done in the immediate vicinity of Batopilas, especially at the Hacienda de San Miguel, situated at an altitude of 1,600 feet above the sea-level, the Hacienda San José, about twenty-five miles farther down the narrow gorge of the Rio Batopilas; at the Cumbre, or summit of the ridge above Batopilas, 8,850 feet above sea-level, where he found columbines, lupines, *Gaultheria,* gentians, alders, and *Ceanothus;* and at the Indian village of Norogachic, about 150 miles north of Batopilas, in the Sierra Madre, at an elevation of about 8,500 feet. This place is surrounded by mountain peaks more or less covered by junipers, madroños, manzanillas, pines and oaks, with a considerable snowfall during the winter months.

Among the plants collected in this region several proved to be new to science, and many were of economic importance. A list of them was published by Sereno Watson in the *Proceedings of the American Academy,* Vol. 21, 1886. The ethnological material was sent to the U. S. National Museum.

Among the plants used by the Tarahumara Indians was one of special interest, a small, turnip-shaped, spineless cactus called *Hikuli,* in quest of which they made long journeys to the mountains of eastern Chihuahua. It proved to be the narcotic "mezcal-button" (*Lophophora williamsii*), also known in Mexico by the name *Peyote,* or *Peyotl.* This plant causes delightful visions and strange hallucinations, and the Indians regard it with great veneration. Like their cousins, the Huicholes of the Nayarit Mountains of Jalisco, they observe certain rites or ceremonies in collecting it, bringing it home, and preparing it for use, which recall the superstitious practises of the *rhizotomi,* or root-gatherers, of ancient Greece.

Dr. Palmer's next expedition was to the state of Jalisco, where he made extensive collections, especially in the vicinity of Guadalajara. Not far from this city he descended into a wonderful barranca, or canyon, never before visited by a botanist. The account of his discoveries at this time recalls Schiede's description of his descent into the Barranca of Teocelo, near Jalapa, in the state of Veracruz.[6] His collection of this year included about 675 species, many of which proved to be new. A preliminary report of the botanical results was quickly prepared by Sereno Watson and published in the *Proceedings of the American Academy.*[7]

The following year he collected near Guaymas, the seaport of Sonora, on the island of San Pedro Martir, in the Gulf of California, and at Mulejé and Angeles Bay, on the gulf coast of Lower California. The results were also published by Watson in Vol. 24, *Proceedings of the American Academy,* 1889.

During June and July, 1888, he collected for the U. S. Department of Agriculture in the counties of Kern, Tulare and San Bernardino, California. A list of his collections at this time, published by Vasey and Rose, is the initial paper of the "Contributions from the U. S. National Herbarium," Vol. 1, 1890. The next year he returned to Lower California, collecting at San Quentin and Lagoon Head, on the Pacific coast, Cedros and San Benito Islands, and once more on the interesting island of Guadalupe, some distance off the coast. An account of the plants collected at San Quentin and a partial report of those collected at Lagoon Head were published in Vol. 11 of the *Proceedings of the U. S. National Museum,* 1889. An account of the remaining plants from Lagoon Head together with those collected on the coast islands above mentioned was published by the same authors in Vol. 1 of the "Contributions from the National Herbarium," to-

[6] "Botanische Berichte aus Mexico, mitgetheilt vom Dr. Schiede," *Linnæa,* Vol. 4, p. 233, 1829.

[7] "List of Plants collected by Dr. Edward Palmer in the State of Jalisco, Mexico, in 1886," *Proc. Am. Acad.,* Vol. 22, pp. 396–465, 1887.

gether with a short list of plants from Lerdo, in the state of Sonora, Mexico, at the head of the Gulf of California. At the latter place he collected great quantities of a parasitic fleshy plant, *Ammobroma sonoræ,* the "oyutch," or sand-food, of the Cocopa Indians.

In 1890 he spent three months in Lower California, collecting at La Paz, Santa Rosalia and Santa Agueda, as well as upon Raza Island and the island of San Pedro Martir, in the Gulf of California; and three months in southern Arizona, collecting at Camp Huachuca, Fort Apache, and Willow Springs. He also made two trips to Alamos in the mountains of southern Sonora, the first during the latter part of March and beginning of April, the second in the month of September. The results of these expeditions were published by Dr. Rose in the "Contributions from the U. S. National Herbarium, Vol. 1, pp. 91–128, 1891. In 1893 he collected in southern Idaho.

He afterwards collected in the more tropical regions of Sinaloa and Colima; at Acapulco, the seaport of Guerrero, from which the galleons of the ancient conquistadores sailed to the Philippines; and in the Territory of Tepic. Several times he has revisited the interior states of Coahuila and San Luis Potosí, collecting among the pines and oaks of the mountains, as well as on the arid plateau and in the warm moist region of the lower land near the Gulf of Mexico. He has penetrated into the heart of Durango, making two trips to the Sierra Madre of that state, once in 1896 and again ten years later, in each case going as far as the newly built railroads would take him and making extensive and often painful journeys to lumber camps and mining regions in the mountains. In 1907 he revisited Tamaulipas, collecting especially near Victoria and Gomes Farias. In 1908 he revisited Chihuahua, this time collecting near the capital and at the neighboring stations of Santa Eulalia and Santa Rosalia.

His last trip, in 1910, was to the gulf coast, in the vicinity of Tampico, Tamaulipas.

From all of these expeditions he returned laden with a wealth of material, his specimens remarkable among those of all collectors, not for their prettiness, though they were often beautiful, but for their completeness, showing when possible bark, root, wood and seed-pods or fruit, as well as leaves and flowers. He did not content himself with a single example, but in spite of difficulties would often bring a whole series, to illustrate vegetative foliage and branches as well as flowering branches, knowing that the aspect of the foliage might vary on different parts of the same plant, and that entire plants might differ according to their situation. He accompanied the specimens by accurate notes as to locality, habitat and season, not disdaining to give local names however barbarous they might sound to ears tolerant only of classic Greek and Latin; and he noted the taste and odor of bark and wood and leaves as well as the color of flowers and the uses of fruits, seeds, herbs and roots, together with the virtues attributed to them by the simple natives, no matter how foolish such information might appear to the eyes of the learned.

And now, as his busy life is nearing its close, enfeebled by hardships and almost incessant physical suffering, he sits close to the fire with his great coat around him. His last set of plants has been disposed of. Is his task finished? He can not bear to think so. He had planned to do so much more. As he closes his eyes he has visions of palm trees reflecting their crests in the still lagoon; or perhaps he hears the tinkling of bells as flocks of goats wander across the sunny plain and climb rocky hillsides dotted with cactus, maguey and yuccas; or perhaps he is once more among pines and oaks on a mountain top, or in moist forests gathering orchids and creeping arums. His old enthusiasm comes back; his pulse throbs with renewed vigor. No, the end is not yet. Once more he prepares his pack; his staff stands in the corner. He unfolds the map. To-morrow he will start off, but to what fresh field he can not yet decide.

It has been impossible within the limits of this paper to do more than enumerate many of the localities explored by Dr. Palmer. To give a detailed account of his work would fill hundreds of pages. Every student of North American botany can bear witness to its value. We have already heard the testimony of the distinguished botanists, Professor Gray and Dr. Torrey, given in the early part of his career. He has added hundreds of species to science and many more of his collecting remain to be described. Scarcely a monograph of a family or genus appears, including representatives in Mexico and the southwestern United States, but among the species described are new ones based upon types collected by Edward Palmer. My list thus far reaches 1,162 new species of flowering plants discovered by him, but I am sure that this does not include all. The composites lead with 259 species. It is not possible to tell definitely how many well-established species bear his name. I have counted 200. It is pleasant to think they will continue to bear his name for centuries to come, eternal witnesses to his wonderful activity, forming a monument more lasting than sculptured marble, recording the services he has rendered to science and his fellow men. And in all the years to come no history of American botany will be complete without an account of the work of Edward Palmer.

FREUD'S THEORIES OF THE UNCONSCIOUS

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ONCE upon a time it was the fashion to demonstrate witchcraft by sticking pins into the unlucky suspect. If any spots were found that appeared insensitive to pain, the unfortunate was forthwith declared a witch, with dire consequences to herself. Now-a-days such anesthesias are recognized, not as signs of a compact with the devil, but as symptoms of that mysterious disease of personality, hysteria.

This reversal of the point of view is typical. We have come to look upon many phenomena that were formerly ascribed to supernatural agencies—crystal gazing, second sight, hallucinations, double personality, possessions, ghosts, even mediumship—not as manifestations of supernatural powers, but as due to an abnormal condition of mind in the subject. In less enlightened days the Miss Beauchamp of whom Prince tells us in his "Dissociation of a Personality," who was several personalities by turns and had, as a rule, as one personality no recollection of the acts she performed as another, might have been burned as a witch. To-day she is a problem for the psychologist.

As knowledge of the psychological nature of such abnormal phenomena has grown, the need has increasingly been felt for some comprehensive explanation of their character. Here, for example, we have a girl (in a case reported by Janet) who has nursed her mother through a painful illness from consumption, resulting in death. The poverty of the family would not allow her even proper nourishment for her suffering mother. Her grief and despair may be imagined. But after the funeral she has apparently forgotten the whole series of events; the entire "complex" has dropped from consciousness. She is bewildered by any mention of the circumstances. But, on occasion, she falls into a trance-like state, in which she rehearses the circumstances of the illness and death of her mother with the utmost fidelity. And then, suddenly, she is normal again, but again she has no recollection of the crisis through which she has just passed. Here is a series of events apparently split off from her conscious personality altogether, yet instinct with energy that at time brings it to the surface. Here is another hysterical patient who has forgotten all about the shock that the physician suspects must have occurred as the starting point of her disdisease, and yet in hypnosis the whole thing comes out as vividly as ever. Consciously it could not be recalled, and yet it was existing and working; for it is a peculiarity of such split-off complexes that they may cause all sorts of conscious disturbances, though the patient himself has forgotten all about the event which started the disturbances, or sees no connection between it and the disturbances which it has set up. Here, for instance, is a young German girl (the classic case of Anna O. reported by Breuer and Freud), well educated, knowing some English, yet not using it as fluently as German. At a certain period in her life she suddenly becomes unable to speak or read her mother-tongue, and is obliged to use English altogether. Finally, in a hypnoidal state, she remembers that, once while she was watching by the bedside of her father, she was frightened by a sudden hallucination. Terrified, she tried to pray, but all that came into her mind were the words of an old English nursery rhyme. The shock, and her manner of reaction to it, caused her to forget her German, and to retain only the English, which had come to her aid at this critical period. There was no connection in her mind between the shock and the disturbances which it had left behind, yet the association, though not a conscious one, had been set up somewhere, somehow.

But all this is abnormal. We do not have to go so far afield to see instances of the same mysterious workings. Who of us has not had the experience of giving up a knotty point in despair for the time, to come back to it and find that our ideas had somehow fallen into place, had apparently worked themselves over without our help. Or how often a name that we have tried unsuccessfully to recall pops into our mind in the midst of some other train of thought. In such cases we have not been dealing with conscious activities as we know them. What has been the process? What has been going on?

It is such considerations as these that have led to the building up of theories of unconscious action, which fill out the gaps in our conscious life. By unconscious action we understand action which goes on without our being aware of it, and yet which seems intelligent, adapted to a purpose. In short, it is activity which it is hard to differentiate from conscious action, except in its lack of this very property of awareness. Most psychologists to-day admit that activities which are more or less like conscious activities go on under the threshold of consciousness; but the orthodox psychological explanation is that they are mere physiological activities, complex changes in the neurones, and that there is nothing mental about them. The brain itself is so complex, they say, that there is no need of supposing that we really think and feel unconsciously, all that occurs is a change in physiological arrangement. The mental and the conscious are co-extensive terms. On the other hand, those who have dealt most with the abnormal phenomena, and are less at home in the field of pure psychology, see in such conscious activities something mental as well. The phenomena are so complex, they say, that if they occurred in an animal, for example, we would unhesitatingly call them mental. They are of course physiological, but it is hard to explain their apparent intelligence without supposing that they are mental as well. The conflict is very like that now waging between the two schools of animal psychologists, those who would reduce everything in the life of the animal to a series of mechanical reflexes, and those who look for signs of conscious intelligence. Like this conflict, too, it is one which can never be decided by introspection, it is only as results accumulate that the balance will swing to one side or the other. In accordance with the law of economy that regulates scientific thinking, it would seem that such activities ought to be explained in physiological terms if it is possible to do so; in this case the question becomes: are they too complex to be so explained?

The thing of all others most needful here, then, would seem to be more evidence as to the nature of such unconscious activities. Such a body of evidence has been brought forward by Professor Freud, of Vienna, whose work is just beginning to be known in this country. Professor Freud is primarily an alienist, a former student of Charcot at the Salpétriêre. In the course of a long practise with neurotic patients, he has arrived gradually at theories of the mechanism of the unconscious, which, if they are substantiated, will go far to revolutionize present psychological conceptions.

Freud's theory is unique in that he supposes the region of the unconscious to be built up of two distinct layers, and that he would explain all the facts of unconscious action as due to the interaction of these two layers.

The upper layer is a sort of vestibule to consciousness. When, for example, as in the case cited above, we try in vain to recall a name, and later find it coming of itself into consciousness, Freud would explain the case as follows: The train of conscious activity set up by the effort has, as soon as attention was turned away from it, sunk below the threshold of consciousness. But it does not at once die away. The activity rather goes on exactly as though it were in consciousness, new associative connections are made, and by and by the associative train succeeds in reaching the name of which we were in search. This now appears in consciousness, seemingly out of all associative connection, and yet a train of association has led to its discovery, only it was a train of unconscious association. So during the day we break off scores of trains of thought without carrying them to a conclusion, because they are too trivial, too complex, too unwelcome, to occupy the mind further. Such trains of thought drop below the threshold, and there may form new associative connections. If these are strong enough, they may again appear above the threshold, apparently without cause. If such connections are not formed readily, the activity may die out without effect. Or such a train of thought may form still other associations, and sink to lower depths of the soul, still to be considered. This upper layer of the unconscious, then, which we find in Freud's theory, is very like the usual sense in which the word "unconscious" is used, especially by those who would see something mental in its activities.

But the unique contribution which Freud has made to the subject is in his theory of the lower layer of the unconscious, which is in many respects totally different in its structure and activities from the upper layer which we have been considering. In order to see his conception more clearly, let us follow for a moment the development of the individual. We all know that the child exhibits many tendencies which in the adult would be signs of criminality, insanity or abnormality. Our conscious personality as it exists to-day is the result of a long process of growth, each stage built on the ruins of the one beneath. The child is savage, primitive; it is only by degrees that he becomes adapted to the restraints of our modern civilization, and represses his old activities. But now, says Freud, such repressed activities leave their traces behind. They may not seem to affect us consciously; we may have even forgotten many of the old ways of thinking and acting, but their traces still exist. What has become of the energy which went to the gratification of our old selfish, individual, feral, modes of thought and action? With most of us the energy has found for the most part new outlets, it has produced the motive force for new developments. It has been "sublimated" to higher uses. But the draining off of the energy from the old modes of action has not been complete. The old primitive tendencies still persist unconsciously in the best of us, and will crop out in some form or other if the provocation be sufficient. We have repressed our childish desires so long that we may have forgotten that they ever existed, but yet they are not quite dead. Particularly is this true in the realm of sex—for Freud holds that the child has a sex life of his own as truly as the adult. It has, to be sure, not yet come to a head in the sexual organs, but it is none the less existent, and in ways which in the adult would be called perversions; which, indeed, if not repressed, are the origin of perversions in later life. Now these old ways of sexual satisfaction are usually repressed under the influence of the environment, yet the tendency to their gratification still exists; we may see it cropping out in the most normal of us in dreams, for example. The energy that went to the satisfaction of such impulses has for the most part been drained off into new channels, but a little of it still remains locked up with the old complexes. Perhaps none of us have as much energy at our disposal for mental work as we ought to have, for some of it still is attached to old and outworn tendencies, making it a little easier and a little more possible for them to come into operation under favoring circumstances than for new tendencies so to do.

Now, for Freud, it is of just such cast off complexes, each with its own complement of energy, that the lowest level of the unconscious is made up. All the unethical acts and unsocial ways of thought of the child, repugnant to us to-day, still exist in the lowest dark chamber of the soul, not strong enough to break out into action, but alive. It is the penalty which we pay for our civilization, that it imposes standards of thought and action which are foreign to the deepest tendencies in us, modes of life of the cave-man and the ages before civilization, which have left their marks on the soul forever. And for all of us there has been some strain in adjusting to its requirements, resulting in the abandonment after a struggle of the old racial ways, and the substitution of newer and more ethical modes of action. But a part of our personality still remains in the troglodytic stage. We may not allow this part expression; we may not even be conscious that it longer exists, and yet it lives and works below the threshold, just as the remembrance of the death of her mother still affected the girl, though consciously it had lapsed. With the split between childhood and adolescence, the chasm between the old and the new becomes still wider; we turn our back more and more on the old ways; they lapse from consciousness more and more completely. Childhood seems a little alien to all of us; there has been a "transvaluation of all values" so that the remembrance of how we thought and felt then comes to us with the mark of a little strangeness upon it. It is strange just because we have cast it all out, we have "put away childish things." But in the dark limbo of the unconscious they still live on, unconscious though we may be that such is the case. The lowest level of the unconscious is thus far removed from consciousness in its modes of functioning. The conception that such tendencies still function, still need continual, though not conscious repression, is the essential point here.

But now what is the mechanism that prevents us from knowing that these old tendencies are still striving upward toward conscious expression? Consciousness is guarded from a knowledge of their existence and their activities, holds Freud, by the interposition of the upper level of the unconscious. This acts like a censor, a guard at the gate, and will not admit to conscious expression these outworn complexes, because of the pain which they would cause us if we were compelled to take account of them in our thinking. It would require too much energy consciously to keep them down; so it is the function of the upper level of the unconscious to save consciousness all this trouble, and to leave it free for other things. This it does, in ordinary circumstances, so well that we are not even aware that any repression is going on, or, indeed, that there is anything to repress. We have repressed our old complexes so long and so well that the act of repression has dropped below the conscious level; we are not aware of its existence. But, on the other hand, it is continually going on, for the old complexes are always striving up to expression. And so the system of energy in the unconscious is a two-way system; the upper system keeping down the lower. If this be true, how different is our mind from the report which consciousness gives us. Outwardly, all is calm and placid, and yet beneath the surface is the mighty conflict always going on. We are like citizens sleeping in security while outside the gates the battle rages hot between our protectors and our enemies. Fortunately, it is our protectors who are usually victorious; the repressive force of the upper level is strong enough to prevent the emergence of the denizens of the lower stages. But this is not always so. Occasionally the assailants find a breach in the fortifications, or a weak spot in the line of battle, and echoes of the conflict come to us within.

To abandon figures, the lower level of the unconscious may under certain circumstances win a partial victory, and some feature of the old complex may arise in our minds. This may happen in the following way. Suppose that a train of thought broken off during the day, and sinking to the upper level of the unconscious, works out there to a conclusion which permits it to be brought into associative connection with one of the complexes on the lower level. The whole process has been unconscious; we are not aware that such a connection has been made, and yet in the trivial event of the day there has been some element, some common feeling tone, some phrase, some suggestion, which is like enough to the old complex to form an associative connection with it. Suppose that during the day we express some slight concern about the health of a near relative, and, in the pressure of work, forget about the matter. Under the threshold, on the upper level, this train of thought may spread further. Now it is one of the traits of children that they have at first little sympathy and love for their younger brothers and sisters. It is not uncommon for them to express a wish that they would die, that they might have more attention from their parents. For death for the child means of course only an absence; he has no conception of its real significance. But such an idea is foreign to the adult mind; it has been so repressed and was expressed at so early a stage that we can hardly realize that it ever existed. However, on Freud's theory, it still does exist, and is continually being repressed by the upper levels. Suppose now that the train of thought having to do with the health of the relative in question works out to a conclusion below the threshold which tends to call up the old complex. This is at once given new energy, its repression is more difficult. And yet it does not emerge consciously. But at night, when the inhibitions are down in sleep, when the repressive force is not quite so great, it makes a supreme effort, and gets through—in a dream. We may awaken terrified from a dream of the death of the same relative who caused us the concern during the day; what gave the motive force to the dream was the old childhood complex, which in this case has, by the help of the new energy, succeeded in breaking through into consciousness. For Freud, the motive force behind a dream is always that of some old complex in the depths of the soul; the dream is a deeply significant revelation of the true nature of our unconscious life, to him who knows how to read it.

This last qualification is important, for it usually happens that the inhibiting force, though not able to completely prevent the emergence of the buried complex, distorts it almost beyond recognition, so that the dream seems to us absurd, disconnected, void of all meaning. This distortion is sometimes so complete that there is only here and there a hint of the true meaning of the dream; it seems to be made up from trivial events of the day alone; but in such cases close examination will show that rational association of such events has been carried on through the complex, which has served as the connecting link and given new energy which permits the trivial events to recur in the dream, though openly the complex does not appear at all. Such was the dream of the woman who saw her nephew lying dead, and yet felt no grief. Now it chanced that on the day before, she had bought a ticket to see her lover, from whom she had parted, in a public performance, and was looking forward eagerly to the event. Some of the details of the dream seemed to suggest that there was some association with this fact; and, indeed, it was found on analysis that the last time she had seen her lover was at the funeral of another nephew. It was as though she had said to herself, "If my other nephew dies, I shall see him again." Do we not perhaps see here the activity of the old childish way of thinking that would sacrifice anything for a moment's happiness for the individual? And yet that complex had not appeared at all in the dream as such. It is thus Freud's thesis that the dream never says what it means, that it is the product of a compromise between the two systems of energy. The complex is distorted in getting around the censor, and thus there arise all sorts of symbolic and indirect ways of expression; the complex is only alluded to in the dream in allegorical ways, or under cover of the trivial events of the day that stand in connection with it; it is not expressed directly. Blood and fire in dreams may appear as sexual symbols; the symbolism may be very complex, as in the case of some of the symbols of primitive man; associations may be determined in the most superficial ways; for example, one person may stand for another in a dream on no more basis of identification than that both wear eyeglasses. The complex makes use of any possible associative connections in order to utilize a little energy to strengthen itself. And it is of course also true that the more indirect and symbolic the associations, the less likely we are to suspect the complexes which are manifesting themselves through them, and so much the more likely will the complex be to avoid the censor. It is as though the complex, in its mad desire to escape, disguised itself and slipped around the back way. It succeeds in escaping, but its disguise alters it so beyond recognition that even its best friends will not recognize it.

Thus in the dream we see the conflict of the two systems of energy, and, if we are skilled, we may even interpret the signs as the woodsman would do, and tell what complex has passed that way, and how it was clad. For the first time the psychology of dreams is thus given a coherent setting, which shows it as a type of activity not foreign to our usual modes of thought, but of one piece with them. For the dream is only one illustration of this conflict. What, says Freud, are the symbols of the artist and the poet but just such disguises, the product of the conflict in his own soul between the primitive and the civilized ways of thought? Other observers have already shown that the root of art is in sex; here we see that it is through the symbolism of a sex-conflict that it develops.

Now, suppose that the complexes are a little stronger, have not been as well suppressed as in the normal individual; in such a case they may break out as hysterical symptoms or obsessions—yet the emergence is not complete, though more complete than in the dream, for the individual still has gaps in his conscious memory with regard to the ways in which the complexes are connected with his symptoms, or he may have forgotten the origin of some of his symptoms altogether. And yet in every case his neurosis goes back and roots in the strength of just such complexes, which have seized on events of his adult life somewhat similar to them in nature, and through the breaches thus made have burst forth into a real, if detached, life.

Shocks, traumatic experiences, cause forgetfulness and splitting of personality, on this theory, because they resemble sufficiently in some respect the old childhood complexes, and these latter are for one reason or another so strong that the experience forms its associative connections with the older complexes, and not with conscious personality. So it drops below the level of consciousness, to in turn strive to rise to the surface. The hysterical symptom is then a symbol of the conflict between the two tendencies. If there were no conflict the old complex would emerge wholly; that it emerges in indirect and symbolic ways is additional proof of the conflict which is going on. One must, then, have reached a certain stage of ethical development, must have repressed old tendencies, in order to develop a neurosis.

It is of course true that this repression of the lower by the upper is in general good for the organism; it is well that consciousness should be left free. The fact that it miscarries at times and a neurosis or a nightmare ensues is only because of the relative strength of the complexes, and not because of a defect inherent in the system itself.

Thus for Freud the most real part of the drama of the soul goes on behind the scenes. Most things that we think we do from conscious motives, most of the thoughts that come into our minds, are but the surrogates and the symbols for the processes that go on beneath the threshold. Ideas are so censored before they get admission to consciousness that we have often little notion of their real nature, and can only wonder that the apparently meaningless idea should haunt us so.

If these conclusions are substantiated, we seem to have a new light shed on the old question of the unconscious. It becomes for us the most real part of ourselves; the expression of our deepest tendencies. It is a realm far larger and far deeper than consciousness; it holds secrets that we thought lost forever. The psychologist would explain the unconscious from the nature of consciousness; Freud, on the other hand, explains consciousness from the nature and function of the unconscious.

The assertion that much of our thinking is symbolic in its nature, due to the fact that it serves as a sort of safety-valve for the escape of our repressed complexes, is of course a problem which can never be solved by appeal to consciousness alone. And it is so with most of the other positions which Freud has taken; we are following pathways where introspection is no guide. Thus he would have us shift the emphasis in psychology from a study of consciousness over to a study of the unconscious. Consciousness, for him, is but the surface; it is in the depths below consciousnes that true reality is found.

We may then sum up the contribution which Freud has made to the psychology of the unconscious as follows: he has supposed that the unconscious consists of two streams of tendencies, or energy, one stream striving to revive all the time experiences which would be repugnant to us, and which we have outgrown, and the other striving to check the revival of such tendencies. As a result of this conflict, we have introduced into our thoughts and acts, especially in conditions when barriers are somewhat down (as in dreams, lapses, neuroses, reveries), a vast deal of the symbolic and the indirect methods of presentation.

Now is such activity as we have been considering mental in its nature—are the unconscious associations and connections of which we have been speaking really associations and thoughts that go on underneath the surface? Or are we dealing with a very complex degree of nervous activity, and with that alone? Freud nowhere states his own position definitely, though it is perhaps too easy to accuse him of leanings toward the mental interpretation. What he has done is rather to open up new lines of approach to the problem, to give us a consistent and closely reasoned interpretation of observed facts. Psychologists are beginning to recognize that, right or wrong, he must be reckoned with. He has given a stimulus to work along this line that may go a long way toward the ultimate solution of some of our baffling psychological problems.

IMPRESSIONS OF MILITARY LIFE IN FRANCE[1]

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I SERVED 309 days—we counted them from the very first, and shouted every morning "Encore tànt et la fuite!"—as second-class private in the 129th regiment of the line, stationed at Le Havre. I was paid one cent a day, and in addition was entitled, every ten days, to a packet of tobacco at half its market value. That was in 1903–04, under the old (1889) law. University students, teachers, artists, artisans and craftsmen (ouvriers d'art), ministers and men having a family to support (soutiens de famille) had to serve, nominally one year, practically ten months. The rest—two thirds of the contingent—served three years. Any one mentally or bodily deficient was totally exempted. At present, the universal term of service is two years, without exception. Many of the halt and maimed, formerly totally excused, are employed in office work or in the repair shops, which offer a sorry sight. Candidates for the priesthood were for a while placed in the regular troops. Now they serve in the ambulance corps, as do a few determined Tolstoians who stubbornly refused to touch a weapon.

My impressions of the army were unfavorably colored, for several reasons, and my testimony is open to discount. First of all, I was a widow's only son, and was brought up very strictly by my mother. Then, the Dreyfus case was hardly over at that time (it was before the second "revision," and the final triumph of justice), and for the last four or five years I had been an enthusiastic Dreyfusist and attended numberless antimilitarist meetings. I found myself among workmen from the mills of Elbeuf and Rouen. Normandy is a fine country, and the race that lives there still offers splendid specimens. But it is rapidly being ruined by an evil greater than militarism—alcoholism; alcoholism to a degree which I as a Parisian did not dream of. Children seemed to be brought up on "Calvados" (cider brandy). The result can be imagined.

Finally I was stationed at Le Havre, the second seaport in France. The barracks rose right on the quays, and I could see in all its hideousness the gross immorality which prevails in all shipping centers. On the very first day, our sergeant carefully explained to us when to go to

[1] This article is an extract from a private letter in answer to a query concerning the military system of France. It is published by permission of Professor Guérard.—David Starr Jordan.

the brothels (on the day of sanitary inspection), and how to tell a diseased woman. I received a shock which I remember clearly to this day. Yet the fault lay not with militarism, but with social conditions. These being granted, our sergeant's eloquence was to the point;[2] and there was some advantage in my being compelled to realize "how the other half live."

All educated conscripts, serving one year, were segregated, and had to study for becoming reserve officers. I wanted most particularly at that time not to become an officer, even in the reserve. So I did not go in with the special company of "dispensés," but remained with the "skimmed milk." The social and intellectual level among the dispensés must have been much higher. I am not so positive about the moral level. They were kept more busy, had more intelligent work to do, and their instructors—officers and non-coms—were picked men. But I had the advantage of seeing more of the real thing. I did not suffer in the least from my position. The fact that I was the only educated conscript left in the company (I was then twenty-three, had spent two years in England, and held a few degrees) was a great advantage. I was made instructor of the illiterate—three half-witted peasants, two of whom did not even know that France was a republic. I gathered a library of 600 volumes for the use of the soldiers. I coached my sergeant major for an examination. Thus I had congenial work instead of the usual fatigue duties (cleaning the room, etc.), and after a few weeks of gradual adaptation I had a fairly pleasant time of it.

From the material standpoint, life in the army is on a higher level than the lowest among the poor (leaving out the destitute), although not quite up to the average. My terms of comparison are the London slums, on the one hand (I spent a year at Toynbee Hall in Whitechapel), and on the other hand, the conditions which prevail among ordinary working people—my neighbors and acquaintances—in Paris. Food is coarse and monotonous (boiled beef every morning), prepared in bulk by unskilled cooks, but it is abundant, and cleaner than the fare afforded by cheap restaurants. I tried the canteens, the non-coms' mess (by special privilege) and the popular eating-houses near the barracks, and went back in disgust to the plain, wholesome regimental beef. Cleanliness is enforced in an unpleasant, rough, but efficient way; hair cropt short, frequent hot shower baths (thirty in a room at times!), sea-bathing in the spring, on a beach of brick bats and tin cans; walls kept whitewashed and coal-tarred; lavatories disgustingly primitive, but disinfected every day. Our captain "took pride" in the feet of his

[2] Our sergeant was unwittingly following in the footsteps of Field Marshal Lord Roberts. Cf. Lord Roberts's famous circular-memorandum 21 and W. J. Corbet's comments thereon in "Bella! Bella! Horrida Bella!", *Westminster Review*, March, 1902.

company, and inspected them repeatedly. The amount of work was not excessive for any but weaklings—soon weeded out and put to sedentary work; it was generally hard and prolonged enough to prevent habits of laziness from being formed. On the whole, a very unpleasant experience for any person of fastidious tastes and habits; tolerable for healthy individuals of an adaptable type; satisfactory for the great majority.

From the moral point of view, the question is more complex. I no longer hold, as I did in the fever of my Dreyfusism, that the army is the school of all the vices. Such exaggerated statements would harm the best cause. The indictment may have been true of the old professional army, recruited exclusively from the lowest strata, and entirely separated from the rest of the nation. Yet I have known veterans of the second empire who were simple-minded, honest, kindly, delightful old fellows. A regiment is not much worse than a big factory. Factory life in Europe is bad enough; military service extends its evils to agricultural laborers, and also to men who would otherwise have escaped these lowering influences. As for traces of moral uplift in the army, I have totally failed to notice any. War may be a stern school of virtue: barrack life is not. Honor, duty, patriotism are feelings instilled at school; they do not develop, but often deteriorate, during the term of compulsory service. Daily drudgery deadens enthusiasm. That is probably why so many French "Nationalistes" tried to dodge the law and shirk their military duty, in order to retain their patriotic feelings intact.

The first evil of military life is that young men are transplanted away from home, and no provision made for sane, wholesome entertainment. Military clubs have greatly developed of late. They are still too few, and so "philanthropic" in character as to frighten most men away. A soldier is free every evening after five. This would be dangerous for most young workmen, who do not know what to do with their leisure hours. The absence of any home circle makes it much worse. For a long time the principle was to send young recruits as far as possible from their place of residence. The idea was to break down local differences, to prevent the army from siding with the population in case of political or social conflict (the brief mutiny of a southern regiment at the time of the wine-growers' riots in 1907 shows that this is a real danger), and to foster the old spirit of exclusive loyalty to the flag. Now, the contrary principle of local (regional) recruiting has been adopted, with a view to more rapid "mobilization," and also under the pressure of public opinion. Even then, it was impossible for most soldiers to go home oftener than once a month. Uneducated young men, friendless and idle, turned loose in the evening in a big city, could do little good. There were certainly temptations to drunkenness and debauchery greater than those which would assail the regular working man. And unfortunately the repressive measures were a farce. The non-commissioned officers, so strict about trifles, sympathized with the drunkards and shielded them, and the penalties were so severe that the officers themselves often preferred to close their eyes. The old ideal of the eighteenth century soldier, "le vin, l'amour et le tabac," remains unchanged to this day. Home-sickness, chiefly among peasants, the squalor and monotony of barrack life among clerks and even students, often lead to a sort of dull despair, which seeks relief in drink (sometimes in suicide, too—there are occasional epidemics). On the evening of July 14 there were hardly half a dozen men sober in the whole company of a hundred.

The officers had no moralizing influence. The superior officers were seldom seen and greatly feared. The subalterns (captains and lieutenants) belonged to three groups: (1) A few clever, ambitious young men. These, all too rare anyway, scorned the routine of barrack life. They spent little time with the men; they studied, or managed to be sent abroad or in the colonies on a mission, or served at headquarters and on the general staff. (2) A large group of young men of means and leisure, not a few belonging to the old nobility. They serve because it is a family tradition, because a man must do something, because of the social prestige of the uniform—not seldom with a view to the larger price which officers command in the matrimonial market in the form of a dowry. They are, on the whole, amiable, inefficient and totally without prestige with their men. The old military caste, still the backbone of the German army, is merely an uninteresting survival in France. Distrusted by the government on account of their royalist opinions, without hope or desire of reaching the highest positions, they give a contagious example of indifference and idleness. (3) Men risen from the ranks—efficient drill-masters as a rule; not seldom kind with their men in a rough way; but often coarse, uncultured, intellectually paralyzed by twenty years of garrison life. The pay is small, the standard of living set by the officers of the second group is high; plebeian or free-thinking intruders are mercilessly snubbed. Silent or open rivalry of aristocrats and commoners, of school-trained and unschooled officers; a general spirit of uneasiness, listlessness and ennui; the most blindly patriotic men not in sympathy with modern France; with all these causes of division, officers as a body can have no real influence on their troops.

As for the non-commissioned officers, I think that Lucien Descaves's sordid and disgusting book, "Sous-Offs," does not slander them. The pay is exceedingly small (from twelve to thirty cents a day), the prospects of promotion not very bright, the work not attractive to a normal, self-respecting man. Only actual failures, or men who shrink from responsibilities in civil life, will take up military service (in subordinate ranks) as a profession. Working men despise them exactly as they despise flunkeys—and they have all the vices of flunkeys—laziness, arrogance and servility. They are undoubtedly inferior to the average foreman or head clerk. In the army authority is much more absolute, obedience more strictly enforced than in civil life. An act of disobedience, "talking back," means not "the sack," but imprisonment, the court martial, the disciplinary companies of Africa or even death. Yet in civil life authority generally implies some degree of real superiority; in the army it is often vested in men flagrantly inferior to the average. Hence a spirit of sullen opposition among the soldiers. The only enduring bitterness which my passage in the army left me was due to the pettiness and tyranny of these underlings. Yet I found among them one unusually able and well-meaning young man, a sergeant-major who died three years later as a lieutenant.

The most demoralizing features in French military life are due to an incontestable progress in the French mind—its gradual loss of faith and interest in military glory. Henceforth the army is considered as useless, dangerous, a burden without a compensation. Authors of school books may be censured for daring to print such opinions, but the great majority of the French hold them in their hearts. Nay, there is a prevailing suspicion among workingmen that the military establishment is kept up for the sole benefit of the capitalists, and the reckless use of troops in case of labor conflicts gives color to the contention. In missions, explorations, aviation, rescue work and on colonial battlefields, the French have shown the same enthusiastic spirit as of yore. But dreary barrack life, without a clear purpose, without an ideal, is more than they can bear. Hence, a universal spirit of indifference and laziness; the main point is to reach the end of the year without trouble, and with the least possible effort (vulgo "tirer au flanc"). Those who succeed in shirking duty are admired and envied as "debrouillards." A disease or an accident, if not too painful, is considered as a stroke of luck; it gives a soldier a few days of far-niente. The military doctors have to exercise the closest scrutiny on malingerers and shammers. To waste time and to escape punishment are the only ideals. There is no incentive to good work. In this respect military life is vastly inferior to industrial life. Men who serve only two years do not aspire to promotion; by working hard for fifteen months, they could barely manage to become sergeants for the remaining four or five. They can't be turned out for inefficient work. I believe the barracks were the school in which the French working-men, naturally industrious and conscientious, learned the terrible habit of "Sabotage." No legitimate superiority is recognized in any way. Education, refinement, cleanliness—verbal, physical and moral—are causes of suspicion. Brute strength, profanity, capacity for strong drink, are titles to respect. Many a workman's son, trained in technical schools, aspiring to better manners and a higher ideal than those of his first associates, is during his stay in the army dragged down back to his old level.

So my general impression is that the army has on the whole no uplifting influence whatever; and without being so black as it was sometimes painted, it has a lowering effect on all except the very lowest. I must, however, mention a few hopeful signs of transformation, which seem to point to a compromise between the army and modern democracy.

The first is the absolute equalization of the term of service. Before 1905 the wealthy classes had either escaped service altogether (paying a substitute, or buying themselves off directly) or served one year in special corps while the rest served five or three. They consistently opposed the general adoption of the one-year term of service, which they themselves enjoyed. Now, it will be easier to further reduce the term of service, first to one year, then to six months. With such reduction the dangers of military life decrease (less idleness, more interest), while its good features (as a school of citizenship and physical culture) are retained.

2. For the last ten years an immense effort has been made for transforming the army into a great educational agency. *Le Temps,* always opposed to any form of progress, recently published a skit in which civil professors in the army (professors of civics, hygiene, geography, rural economy, "prévoyance," etc.) complained that drills, marches and manœuvres were interfering with their teaching. Nay, pacifist lectures were at one time regularly given in French barracks (under General André). Of course it would be more sensible to spend the money directly on education. But the gradual "humanization" of the army is an excellent thing.

3. At the time of the postal strikes, of the railroad strikes, of the Seine flood, the army was called upon to fulfil various duties, and did it admirably. There is a great danger in turning the army into a universal strike-breaking corps, or a body of "compulsory scabs." On the other hand, this industrial use of the army points to a mighty transformation; the war forces could become, as W. James intimated, reserve forces of peace, for great public works, sudden emergencies, national disasters. (Herein again the wit of journalists found a free field; it was announced that nursery-maids had formed a union (syndicat) and struck for shorter hours. The Nth regiment of engineers was detailed to take their places, to the great delight of cooks.)

We must look forward to a gradual transformation, for militarism will not be rooted out in one day. Costly as it is, the nations grow rich in spite of the burden. There is no doubt but France is amassing wealth at a rapid rate, and fast becoming the banker of the world, while Germany's progress is stupendous. France's toll on the foreigner (investments abroad, and expenses of tourists) alone more than pays for the interest of the debt, and the cost of the military establishment. Conservative papers, like *Le Figaro* and *Le Temps* sound notes of warning when new educational or social laws are proposed; but when a reduction of military expenditure is mooted, they prove conclusively that the country is marvelously prosperous, and could afford a few more army corps and a dozen super-Dreadnoughts.

Beside the spirit of mutual diffidence which centuries of hostility have fostered, and which the recent attitude of Germany has revived, the strong point of militarism remains its sentimental appeal. Dreary barrack life is still linked in popular imagination with the sombre but grandiose epic of ancient wars. Men serve their time when they are young and buoyant, when no hardship is unendurable, when even the memories of unnecessary fatigue, squalor, petty tyranny, are transfigured by the general glow of youth and hope. I for instance look back upon these days of servitude with a sort of pleasure. I remember the fun, the marching at the sound of bugles and band, or singing away on the highroad; the mock guerilla warfare around Norman farms in the early morning; the incontestable grandeur of a division in battle array. Soldiering is a pretty game, although murdering is an ugly business. It is possible that wars will be abolished generations before armies are suppressed.

REALITY AND TRUTH

BY PROFESSOR T. D. A. COCKERELL
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REALITY may be conceived of as having three aspects, the knowable or scientific, the imaginable or metaphysic, and the unimaginable or metapsychic. These three elements of being are not in themselves distinct, but depend for their separation on the condition of the perceiving mind. They are so closely interwoven that every part of reality may be said to contain them all; every circle of thought being partly distinct, partly faint, partly broken.

The discussion of the metapsychic appears at first sight to be impossible. Since it is postulated that the content can not be material for thought, how can it be discussed? No creature, indeed, can contemplate its own metapsychic field, but it may contemplate that of others. Our best established science is metapsychic for many animals higher in the scale than the jelly fish. Were man the only living being, he might still afford variation enough for the study of metapsychics on a comparative basis; but with the great field of comparative psychology open before us, the material is more than abundant.

In all this, however, the reality which is described as metapsychic for the one being, is psychic for some other. There can be no doubt that some animals operate in part of our metapsychic field, having, for instance, sensations of smell altogether beyond us. We believe, however, that there is a vast field of reality unrealizable to any living being, and to complete the psychological scheme at the ultra-human end we postulate an all-knowing God. It is a curious question, what must be the psychology of one whose thought circles are all complete, in whose mind there are no attenuated ends of things, fading into the unknown and unknowable. Such a question may be raised, but can hardly be answered by us.

Intellectual progress consists in winning ground from the metaphysic for the scientific, from the metapsychic to the metaphysic. The transition from the third to the first must always be through the second, though its duration therein may be of the shortest. This statement denies, as I think we must deny, the immediacy of knowledge, though not of experience. Knowledge has structure, is built up of varieties of experience, is an organized thing. A single absolutely uniform and monotonous experience, no matter how long continued, could not be a basis for knowledge.

By what process is ground won from the metapsychic? How is the threshold of consciousness overstepped? The mind is a stage, upon which the actors come, and from which they go. Whence are they, and whither do they depart? We can describe in terms of science the accompanying phenomena, but the thing itself evades us. What wonder that mankind has always believed in supernatural, that is, metapsychical agencies!

Reality is a poor word for the totality of being, because it implies to us realizableness. It is only justifiable on the ground just stated, by postulating a being able to know the whole of it. Nevertheless, the practical thing for us is to recognize the continuity of the known into the unknown, without asking what the limits of the latter may be, supposing it to have any.

What is truth? Endless confusion has arisen from the double meaning which has been given to this word. There is practical truth, and abstract truth. The scientific man adheres to the former, the philosopher may talk about the latter.

Science tests things and finds them true, and is only willing to declare them so after examination. Truth then, is the objective side of knowledge, and without knowledge in this sense, there can be no truth. It would conduce to clearness, could we so restrict the meaning of the word, and I believe that in so doing we should have some support from ancient usage. Otherwise, how could we speak of a fact *verified,* made true, if the making true were not a process of the human mind, operating on preexisting reality?

This would leave us with abstract reality, metaphysical and metapsychical reality, but no abstract truth. Truth would be concrete, objective, scientific, something to tie to and act upon. Hence, said William James: "True ideas are those that we can assimilate, validate, corroborate and verify," but he added something to which one need not subscribe, namely, "False ideas are those which we can not." This last postulate would make all ideas false which are incapable of verification, surely an absurd use of the word false. I would rather say that false ideas are those which, having been put through legitimate tests for verification, have failed to pass the examination. False ideas, then, are those which we have tested and could not then verify. Of those which we can not test, or have not tested, it is impossible to say whether they are false or not. Thus we are left with three categories, the true, the false and the candidates for admission into the first group, liable to find themselves ultimately in the second.

The power of verification is apperceptive; we are reminded of Ehrlich's chain-theory to explain certain aspects of proteid metabolism. There must have been an Adam and Eve of knowledge, when two sensations first joined together as the charter members of the society for converting experience, a raw material, into beautiful and marketable truth. Since then the members of this society have closely scrutinized the new-comers, and many have been black-balled. The society is anything but infallible. Not unfrequently it has let in members which afterward had to be ejected with violence, greatly to the discomfort of all concerned. Still more often, I suspect, it has refused to admit worthy candidates who would have been a credit to it. Thus it has come about that many so-called truths are not true at all, for the alleged process of verification was faulty; while supposed untruths may be destined in the fullness of time to be recognized as true.

At this point we must consider the pragmatic doctrine of truth, as expounded by James and others. Pragmatism says, try all things and hold fast to that which is good. Ask always, how does this work? Will it make a good member of the truth-makers' society? It is a doctrine of intellectual dynamics, of activity, of judgment based on knowledge. To this extent it is therefore a wind fanning the flame of intellectual activity, to the end of burning up the dross and extracting the gold. It is the scientific method invading the field of philosophy.

It has, however, a double aim. In testing an alleged truth by its *consequences,* it merely follows the scientific method of determining whether it will, as it should, articulate properly with pre-ascertained truth. It recognizes that *for us,* things are true which have endured the test. This, however, is only the beginning of its quest. It goes further, and asks what things, of those which may be called true, are worth while from a human standpoint. It is inclined to hold, indeed, that this very serviceability is in itself a test of truth. It is for this reason that Professor Schinz calls it "opportunism in philosophy."

The word philosophy, originally signifying the love of wisdom, has come to have many diverse meanings. Quite commonly it is taken to signify a theory of the totality of existence, as, for example, in Haeckel's monistic philosophy. Since it appears that much of reality is meta-psychic, a theory embracing the whole of it must be beyond the powers of the human mind, and, as is certainly the case with monism, we find ourselves in possession of nothing more than a point of view. It is, indeed, with the point of view that philosophy must concern itself, and he is a philosopher who has scrutinized and recognized as a whole the landscape visible from his peculiar point of vantage, without necessarily formulating any opinions concerning what is to him unknown. I would therefore say that one's philosophy is one's attitude toward experience-able reality, and inasmuch as every one must have some such attitude, all are to this extent philosophers. One's philosophy, as thus defined, may be consistent or inconsistent, limited or comprehensive, optimistic or pessimistic, active or sluggish, in almost infinite variety. It is obvious that its character determines to a tremendous extent one's personality, or rather, personality is expressed, and its character for others determined, by the attitude taken.

I am not quite sure that the use of the word philosophy in this way, a way that allows us to speak of the *pragmatic philosophy,* is justified, but that is a minor matter, and may be overlooked in our quest for larger game. The important question is, supposing the world converted to this pragmatic philosophy, what would be the consequences, pragmatically speaking? Would pragmatism itself be pragmatically justified?

At the very outset, it must be obvious that a genuinely pragmatic attitude implies for most of us a noteworthy increase in intellectual activity. It is an attitude which obliges us to inquire, test and form judgments. The pragmatist asks *cui bono?* not in the indolent manner of the pessimist, but as the miner asks for the precious metal, and is determined to find it, no matter what the cost. The pragmatist is necessarily an optimist, for his quest implies from the start that the truth is good and serviceable, worthy to be sought. I think the psychologist and the sociologist might have something to say here about the possibility of a breakdown due to too much pragmatism. Are we not protected to a considerable extent by our very stupidity? Human judgment is a two-edged sword, which has often wounded those who used it. Do not our educational efforts indicate to us daily the limitations of the human mind?

It was the belief of William James that most people are capable of much more than they customarily put forth. He was supported in this by examples of heroic effort and achievement under conditions of stress, physical and mental. Our normal performance in these civilized days far exceeds that of our ancestors of a few hundred years back; ancestors who, biologically speaking, did not differ in any important particular from ourselves. The same peoples, living contemporaneously in different parts of the world, differ enormously in their intellectual performance, according to circumstances. It must be admitted, then, that the depths of the human mind have not been sounded, and that much still unsuspected may yet come forth. Whether we like it or not, education and democracy will place us in a position where we must either become more intelligent or go to smash. If we can stand the strain, all will be justified, and humanity will realize values unattainable by any living being at any previous stage in the history of the world. If we fail, the vision of such possibilities will at least remain as a permanent contribution to human welfare, and perhaps a spur to other and more successful efforts in a time far distant.

After all, the pragmatic position does not demand so much of the individual as might at first appear. We are social beings, and in particular our knowledge and judgments are social products. It is equally unnecessary and impossible for every one to form judgments about everything. A pragmatist need not in any way diminish his regard for authority, provided that this authority represents active inquiry and reasoned judgment. The usages of science suffice to indicate this, for in science there is no arbitrarily constituted authority, and yet the leaders receive their full share of respect. Were we all pragmatists, we should not individually undertake to decide the questions most important for us, but working together we should keenly strive to have them decided on a proper basis. In other words, pragmatism is not only not necessarily individualistic, but must have a socialistic trend if it is to be successful.

For any individual there can be no doubt that a certain ballast due to usage, custom, inertia, or what you will, is necessary. It must be so, also, with society as a whole, and neither for the individual nor for society is it possible to have a complete working philosophy, with all the machinery in view. Mallock once remarked that philosophy is like a coat which can not be buttoned up in front without splitting in the back, and this felicitous image certainly sets forth that inconsistency in the heart of things which has so far baffled all attempts to construct a universal logical system. The reason is, no doubt, that we work only in *some,* not *all,* of the dimensions of reality.

There is, therefore, danger in being too pragmatic. An excess of pragmatic zeal, under the best possible conditions, might possibly lead to the adoption of a too rigid system of values, logically deduced from the physics and metaphysics of the day, but in spite of everything, fatally incomplete. It is the sense of this that gives us pause from time to time, when our intellectual judgment bids us proceed. It has been shown so often that science may stand in her own light, that we have come to regard all things as possibly to be revised. This hesitation, this doubt on the part of those who have done their best for progress, is made the most of by those who cling without thought to the old, and all in all forms too great, not too small, a check on the advancement of the race.

The general outcome of our inquiry seems to be, that if we regard philosophy as an attitude of mind, the pragmatic philosophy may be welcomed as representing a changed emphasis, according well with the spirit and needs of our evolving democracy. At the same time, like every other good thing, it has its dangers, and in some hands it may even be disastrous. As a practical example of pragmatism, we may cite a recent case familiar to all—I mean Mr. Roosevelt's criticism of the Supreme Court. Lawyers had asked, what is written in the law? Mr. Roosevelt asked in truly Jamesian fashion, what difference does it make if this or that decision is rendered? To ask such a question is to find the answer ready at hand, intelligible to the least learned inquirer.

The answer so obtained may even be used to interpret the law itself, having regard for its obvious spirit and intent, rather than the technicalities of some previous case. The pragmatism of nature is expressed through natural selection and the survival of the fittest. It is "the difference that it makes" that decides the fate of a new variation. In the long run, our human virtues and frailties must pass under the same law, but possessing conscious intelligence, we ourselves have a hand in the game hitherto played only by the gods. Having memory and foresight, we can even somewhat improve the ancient process, by considering "the difference" as made in the long run, instead of at the moment only, as is the manner of nature herself.

THE COST OF LIVING

BY HENRY PRATT FAIRCHILD
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"THE increased cost of living" is a phrase familiar to almost every American tongue in these days. Newspapers and magazines are full of the topic. A wide variety of investigators are earnestly searching for the causes, and divers explanations have been offered. Over-production of gold, the tariff, the trusts, cold storage and a host of other things have been mentioned—all, probably, with more or less of truth. Yet it is amazing to note how little attention has been paid to the most obvious and easily comprehended cause of the high prices of one great class of commodities, *i. e.,* the food of the people. This is by far the most important aspect of the problem, and its primary and fundamental explanation lies in a perfectly simple and concrete fact—namely, the increasing proportion of the population of the United States which may be classed as city dwellers rather than country dwellers; in other words, the preponderance of the urban population.

The food element of the high prices problem is so thoroughly predominant in all discussions of the topic that one might almost say that, in the popular mind, the high cost of living is synonymous with the cost of food. The high prices which are causing such consternation in the families of the land are the prices of meat, eggs, butter, milk, bread and vegetables, and it is to this class of commodities that the following considerations apply most directly. These are all, primarily, the products of the country. We may then carry our analysis a step further and say that the cost of food is the cost of agricultural products. It may be observed, in passing, that many other necessaries of life, beside food, are products of the country. In fact, practically every commodity is derived ultimately from the land, and what is true of food is more or less true of other commodities, in proportion as they are the products of the extractive, rather than of the manufacturing industries. At the same time, most of the present discussion of this topic centers around that class of commodities, originally mentioned, which make up the food supply of the nation, and are directly the result of the application of labor to land. It is to this group that we wish to confine our main discussion.

Let us hasten, however, to disclaim any inclination to minimize the value of the contribution which is made to the wealth of society by the manufacturer, the merchant and others engaged in distinctively "city" occupations. The old idea of the school of French economists, known as the physiocrats, that land is the source of *all* wealth, undoubtedly served a useful purpose at the time, but was long ago abandoned. To-day we readily recognize that any person engaged in any occupation which adds to the total enjoyment of mankind is a truly productive laborer. The drygoods clerk, the manufacturer of shoes, the bank president and the opera singer all make additions to the wealth of society, just as truly as do the farmer and the dairyman. We even go further, and assert that the greatest total wealth of society can be produced only when the efforts of the agricultural classes are supplemented by a certain proportion of laborers in industrial, professional and mercantile fields—the avocations of the city. But there comes a point in the economic development of a nation when the number of those engaged in city occupations—including the occupation of spending time, indulged in by the idle rich and the unemployed poor, who throng the cities—becomes excessive, and overbalances the number of country workers. Have we reached this point in the United States?

The price of food stuffs, like that of every other commodity, is governed by the laws of supply and demand. Assuming stable conditions of fertility of soil, of climate, and of methods of production, the price of agricultural products depends on the proportion between those who produce them and those who consume them. Broadly stated, this is the proportion between the country dwellers and the city dwellers. This proportion in the United States has been rapidly changing within the last century in the direction of the preponderance of the urban class.

When the first census was taken in 1790, there were only six cities with over 8,000 population each, containing in all 131,472 persons, or 3.4 per cent. of the total population of the United States. In 1840 the percentage in cities of the specified size was still only 8.4.[1] But in 1900 there were 545 cities of over 8,000, in which dwelt 33.1 per cent. of the total population. The significance of these figures becomes more evident if we consider the proportion between the urban and rural populations at different dates. In 1790, for every inhabitant of the cities of the specified size, there were 28 persons living in the smaller towns and in the country districts. Fifty years later, there was one city dweller to every eleven country dwellers. By 1880 the proportion had reached 1 to 3.4 and at the last census, in 1900, for each inhabitant of the cities there were only *two* dwellers in the country! Is it any wonder that the cost of agricultural products has gone up? The marvel is that prices did not go up long ago, or that they have not reached a much higher figure.

It may appear that the foregoing explanation is inadequate to account for the suddenness of the rise in prices within the last year or two. To this objection, there are two or three replies. During the last half of the nineteenth century the tendency of prices to rise was offset by improvements in the arts of agriculture, and by the cultivation of new and better lands in the west. The crisis of 1907, by depressing conditions in general, caused a temporary retardation in the upward movement, making it more pronounced as prosperity returns. Moreover, the critical point in the proportion between the urban and rural classes is one which may be reached and passed in a brief period of time. Apparently we have just reached, or are just passing, this juncture in the United States. Finally, the explanation herein offered does not claim to be a complete one. For such a complicated phenomenon, there is undoubtedly a variety of causes, each with its own importance. But the division of population between city and country is the underlying condition which has made the operation of the other causes possible.

At this point the question naturally arises, why does not this state of affairs work out its own cure? Why does not the high price of farm products, bringing, as it apparently must, large profits to the farmer, make country life more attractive, and check the rush to the city, or even entice some of the urban dwellers back to the soil?

The first and most obvious answer to this query is that by no means all the profits accruing from the high price of food ever find their way back to the pockets of the original producer. Farmers have never been able to secure for themselves, for long periods of time or over large areas, the benefits of combination. Under our modern system of supply, the products of the soil pass through a number of different hands before they reach the consumer, and each of the intermediaries must have his profit. A large part of the excess of price over the actual cost of production is absorbed by transportation companies, commission merchants, packers and retail dealers—themselves mainly city dwellers.

But this is only a very partial explanation. The factors which determine residence in city or country are something more than the financial advantages which this or that locality has to offer. That the opportunities for achieving marked success in business, and amassing huge fortunes are greatest in the centers of population is undoubted, and the decision of many a country lad to break away from the familiar home surroundings is forwarded by the hope that he may be one of the fortunate ones who find their place in the city, and win great rewards. Occasionally it turns out so. But it is a question whether the average young man stands a better chance of making a comfortable living in the city than on the farm, and monetary considerations alone could hardly exert such an attractive force as we see in operation.

The lure of the city is something infinitely more complex and intricate than this. A complete and adequate explanation of its power has long been sought in vain. Some of the elements of its irresistible charm are obvious, and may be easily stated—the excitement and variety of metropolitan life, the opportunities for recreation and diversion, the comforts of city houses, the chances for achieving success and fame in many fields, the busy whirl of commercial and social life—but after all, what is all this more than to say, "the fascination of city life"?

There is one condition, however, which has undoubtedly done much to intensify the situation and aggravate the difficulties. That is the immense immigration of the last quarter of a century, particularly of the last decade. The immigrants of an earlier generation—the Germans and the Scandinavians—went west in large numbers and took up farm lands, making an effective and valuable addition to the ranks of agricultural producers. Our modern immigrants settle in the most densely populated states, and in the largest and most congested cities. In 1890, 61.4 per cent. of the foreign-born population of the United States were living in cities of at least 2,500 population. In 1900 the percentage of foreign-born in cities of like size was 66.3, while of the 10,341,276 foreign-born residents of the United States in that year, 38.8 per cent. were huddled in the few great cities having a population of over 100,000. When we consider that only 15.5 per cent. of the native-born population were in cities of that size, it becomes evident how seriously the immigration movement affects the proportion between city and country dwellers—in other words, the cost of living. The census of 1910, after a decade of immigration unparalleled in the history of the nation, will undoubtedly show conditions even more striking and appalling.

The comparatively small increase in the proportion of city dwellers from 1890 to 1900 (from 29.2 per cent. to 33.1 per cent.) may be partially explained by the very slight gain in population through immigration during that decade, while the tremendous immigration of the last few years may largely account for the suddenness of the jump in prices.

To discuss possible remedies for the situation is apart from the purpose of the present paper. A few years ago, when the country telephone, rural free delivery, and the inter-urban trolley began to come into common use, great hopes were expressed that together they would help to solve the situation by promoting communication and fellowship among rural families, breaking up their isolation, and thus making country life more attractive. The results so far seem to have fallen far short of the anticipations. As for the immigrants, a few of the Italians are beginning to take up market gardening in the neighborhood of the great cities, but this movement is very slight as yet. All the efforts of colonization or removal societies, philanthropic organizations, and of the United States government, have produced almost inappreciable effects in securing a better distribution of the foreign-born.

What the future may bring forth in the way of increasing the attractiveness of the country for natives or aliens, time alone can tell. But as long as the rush to the cities continues with unabated or increasing force, it is vain to hope that the cost of food will fail to augment at a corresponding rate.

ALCOHOL—ITS USE AND ABUSE[1]

BY PROFESSOR GRAHAM LUSK
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WHEN the writer was a former student in Munich about 1890, there was a very great quantity of beer partaken of by the inhabitants of the town, and also by the German people in general. The "beer duel" consisted in draining a large jug of beer which was lifted from the table at a given sign, and he who first brought the empty jug back on the table was the winner of the duel. In fact, the writer has heard pleasure measured in terms of glasses of beer partaken. For example, such and such a holiday trip on the Rhine could not be indulged in because it cost the equivalent of so and so many glasses of beer.

A considerable change in the manners of the people was noticed on a visit to Germany in 1906. At a luncheon in Heidelberg, both lemonade and white wine were placed on the table, and the white wine was scarcely touched. This great change has been due to two factors. There has been great development of what the Germans call "Sport." The young men indulge in an out-of-door life to a very much greater extent than formerly. Skiing among the Alps in the winter-time, for example, is something which is the delight of many of the students, and all this has tended to decrease on their part the quantity of alcohol consumed. A second powerful influence is that of the Kaiser's edict that his health can be drunk in water. As long as it was impossible to drink the Kaiser's health in water without its being considered a dire and fatal insult to His Majesty, just so long was it impossible for the development of a temperance spirit.

Besides these factors, the physiologist Bunge has for many years railed at those who would partake of the excreta of yeast, and Friedrich Müller and Kraepelin of Munich have neither of them lost an opportunity before their medical classes to drive home the evils accompanying excessive drinking. They have done this to the great trepidation of the beer brewers of Munich.

At a recent lecture in London, Dr. Mott has said that it was desirable to approach this subject in a scientific spirit and without prejudice, and following him, Sir Clifford Albutt has called attention to the fact that much of the literature of alcohol is of a rhetorical rather than of a

[1] Annual address before the Alpha Omega Alpha Society of the University of Pennsylvania.

scientific order, and has stated that the sooner scientific order and method are introduced the better.

Alcohol is frequently used as a flavor for food. Pure alcohol itself is never taken, but the various alcoholic beverages are prized on account of their various flavors. There is no more powerful stimulant to the flow of the gastric juice than alcohol. Introduced directly into the small intestine or even into the rectum, alcohol may produce a flow of gastric juice. However, it has been shown that a single glass of wine containing between five and ten per cent. of alcohol is as effective as a stomachic as when much larger quantities are ingested. Indeed there can be no doubt that the healthy stomach needs no such stomachic whatever. This is known, because the materials of which ordinary food consists are perfectly digested and perfectly absorbed without recourse to anything beyond the ordinary flavors of the table.

In cases where there is no appetite, it may be that a single glass of wine may help the digestion of food. So Pawlow describes that when he was convalescent from a fever and could digest nothing, a glass of sherry brought about an initial flow of his gastric juice and with its aid digestion of the food was possible. It is stated that the value of a liqueur which is taken with after-dinner coffee, lies merely in its irritant action upon the wall of the stomach—an action which promotes a discharge of material from the probably too well-filled stomach of the individual who has been dining.

Alcohol is also a nutrient material. The publication by Atwater and Benedict showing that alcohol could replace other foodstuffs in nutrition, led Mr. Dooley to remark that his saloon was really a restaurant. In normal nutrition the cells of the body are provided with fuel by fat or by sugar. When protein is given, most of it is converted into fat or into sugar within the organism. So, in the ultimate analysis, it is found that the motions of the cells, which motions constitute life, are maintained at the expense of fat and carbohydrates. When these are oxidized, energy is liberated which impels to motion the particles of protoplasm, and these motions constitute the machinery of life.

Atwater and Benedict gave a man ordinary food for thirteen days. The food contained 2,496 calories, and the man destroyed materials within himself, so that he daily produced 2,221 calories. On this diet, he retained within his body 33.7 grams of fat daily. Then the same man was given a diet for ten days which had the same number of calories as before, but only 1,996 of these were in the ordinary food materials, whereas 500 calories were in alcohol. This quantity of alcohol is what would be found in a bottle of claret. The alcohol was given in six small doses daily. The alcohol was almost completely burned, only a small quantity appearing in the urine and breath. The heat production during this second period, amounted to 2,221 calories daily or exactly the same as in the previous normal experiment. The quantity of fat retained by the patient on the alcohol days amounted to 34.1 grams daily. It is evident from this experiment that alcohol can replace fat or carbohydrates in metabolism in accordance with its heat value. So we can say that the cells of the organism may be maintained in their vital activities by alcohol instead of by normal nutrient substances.

It is apparent, therefore, that alcohol may have a very considerable value as food. If an alcoholic beverage should contain materials other than alcohol such as the extractive materials in Bavarian beer, the food value rises to a very considerable amount. Thus, a liter of Bavarian beer contains 450 calories. These facts, however, do not at all justify the substitution of alcohol for carbohydrates and fats in the dietary.

Many experiments have been accomplished to see whether alcohol has any effect upon the protein balance in the body. Sometimes alcohol has been found to spare protein, sometimes it has been found to cause a waste of protein. The effect, however, of alcohol upon the general metabolism of protein is certainly without very great significance.

Yet there are indications that alcohol does alter metabolism in the individual who partakes of it. Beebe found no effect upon the output of uric acid after taking alcohol with a diet which was free from the precursors of uric acid. This, however, has not been confirmed by others, and Landau found that usually there was a slight increase in the output of uric acid in the urine after the ingestion of alcohol.

Since the nucleus of the cell is characterized in its structure by the presence of nucleo-proteins whose destruction results in the increased elimination of uric acid, it is not impossible that these nuclei are somewhat affected by the presence of alcohol in the body. A similar effect upon the nuclei of the germ plasm may be considered in connection with the idea of the possible transmission of alcoholism through heredity.

Abbott has found that alcoholized rabbits not only show the effect of streptococcus inoculations earlier than do non-alcoholized rabbits, but the lesions produced are much more pronounced than those which usually follow inoculation with this organism.

Laitinen has administered to rabbits one cubic centimeter of pure alcohol per kilogram of body weight, which corresponds to between four and five ounces of whiskey daily for a man. This quantity of alcohol was not sufficient to intoxicate the animal. Animals which had received this amount of alcohol for a considerable period were found to have a much greater susceptibility to pathogenic bacteria than normal controls.

Hodge has found that alcoholic dogs show diminished resistance to distemper as compared with normal animals under the same kennel conditions.

Richards has shown that if the hearts of dogs which have received alcohol for some time be perfused with a nutrient solution containing alcohol, they are much more sensitive to alcohol than hearts of normal controls.

Another experiment which shows apparent change in the organism under the influence of alcohol, has been accomplished by Reid Hunt. Hunt determined the toxic dose of aceto-nitrile CH_3CN in mice, rabbits and guinea pigs. This substance acts as a poison through the liberation of hydrocyanic acid within the body. Hunt found that if animals were given alcohol for several days, their susceptibility to aceto-nitrile was very greatly increased. That is to say, hydrocyanic acid was much more readily liberated within their tissues than in the normal controls. Hunt interpreted this as indicating an increased oxidative power on the part of the cells for the methyl group contained in the poison. However this may be, it is certain that his experiments have shown that metabolism is different when alcohol is given than it is under conditions when fat and carbohydrates form the energy producers which maintain life.

Alcohol has long been given in disease on account of the belief that it was of benefit in certain disturbances of the circulatory system. The value of alcohol under these circumstances has been disputed. The reports of the Vienna General Hospital in 1897 show that $10,000 was spent for alcoholic beverages during that year, whereas in 1905, the sum so expended had fallen to one half. Dixon says that alcohol acts uopn the isolated heart as a food stuff, and favors its contraction. A recent discussion of this subject by Miller, of Chicago, shows that circulatory disturbances in acute affections are of vaso-motor origin, and that the heart itself is usually perfectly able to fully perform its work. He calls attention to the fact that alcohol in certain diseases acts as a cardio-vascular stimulant producing vasco-contraction of the blood vessels and thereby favoring the circulation. However, if the dose which brings about this reaction be but slightly exceeded, there is paralysis of the vaso-motor centers with resulting dilatation of the blood vessels. He regards alcohol, therefore, as a drug which is to be used in these conditions with extreme care.

Alcohol has a profound effect upon the central nervous system. There are two theories with regard to its action. By some it is considered a stimulant, by others it is thought always to cause depression. Small amounts of alcohol may bring about an increased sense of liveliness and a general feeling of well-being which is most pronounced when the lights are bright, and the company congenial. Larger quantities induce incoordination of speech and movement, whereas still larger quantities result in complete anesthesia which may be fatal to the individual. For the first few minutes after taking alcohol, it has been found that a larger quantity of physical work may be performed. This is followed, however, by a period of depression during which the quantity of mechanical energy which may be expended by the individual is greatly reduced. The sum total of the effect is very decidedly to reduce the amount of mechanical work which can be accomplished during the day. It is on this account that alcohol is no longer given to soldiers on the march in the hope of increasing their endurance. The actual result would be quite the contrary.

Experiments regarding the action of the brain after taking alcohol as compared with its action before taking alcohol have been made by Kraepelin. Typesetters were used as subjects. It was found that those who had partaken of alcohol made a greater number of errors and worked less rapidly than those who were abstemious. Kraepelin has found that this effect lasts as long as twenty-four hours after alcohol has been taken. Curiously enough, those who had taken alcohol thought they were doing their work to better advantage than those who had not.

Other experiments have been made upon people, the test being the length of time which was required to memorize twenty-five lines of poetry. Here, when alcohol was taken before breakfast, it was found that the length of time required to memorize was increased 69 per cent. Also, when these individuals were requested to repeat the lines which they had learned, it was found that they did so less readily and made more errors when they had previously taken alcohol, than when they were free from the effect of this drug.

It is very apparent from such experiments as these, that alcohol does not stimulate to mental activity. The theory of Schmiedeberg is that the effect of alcohol is always a depressant one. The first depression upon the mind acts upon those highest faculties which are developed latest in life. That is, the faculties of self-control and self-respect. If these faculties are paralyzed first through the depression of alcohol, then it is as Cushny has pointed out, as though the brakes were removed from the mind, and the man becomes a child again. He becomes regardless of the ordinary conventions of life, regardless of the feelings of other people, regardful of himself alone. It is easy to see that where restraint is removed from the mind so that the normal action of self-control is abolished, the individual becomes open to all kinds of suggestions which he otherwise would not suffer. The mental condition is truly pathological.

It is thus that alcohol becomes the principal power behind prostitution. It is thus that the saloon in politics becomes dominant. The saloon through the alcohol which it furnishes is perfectly able to reduce the self-respect of the individual to such a level that he is glad and willing to accept a bribe for his action with regard to a political matter. It is easy to see to what extent alcohol becomes the auxiliary of crime.

It is stated that 60 per cent. of the crimes of violence are due to drink. All these various activities which are due to alcohol tend to break up homes, and indeed Cushny has stated that if alcohol were a new synthetic drug imported from Germany and a few cases of alcoholism had been discovered as resulting from it, there would be such an outcry against it that it would be forever prohibited. A much more valuable drug, cocaine, he says, has nearly come to this fate on account of a few isolated cases in which the cocaine habit has been formed. The writer is not a teetotaler, and yet he does not think that any one can listen to an exposition of the effects of alcohol without being willing to join in a movement for its entire prohibition, provided such a prohibition could be really effective. The trouble, of course, with such movements has been that prohibition has not in reality prohibited.

The English medical journals have of late contained several articles regarding the relationship between alcohol and insanity, and also between alcohol and heredity. Dr. Mott, who is both a physician and a pathologist, quotes from Dr. Branthwaite, that 62 per cent. of the alcoholics committed to reformatories under the English Inebriates' Act, are found to be insane or mentally defective. However, Dr. Mott is very unwilling to believe that alcohol is the cause of insanity in any such proportion. He attributes the statistics mentioned above to the marked intolerance of the mentally defective for alcohol. Dr. Mott has made many autopsies in connection with his service at the Charing Cross Hospital and the Claybury Insane Asylum. In the general service of the Charing Cross Hospital he has found cirrhosis of the liver in about 7.7 per cent. out of a total of 1,099 adult autopsies, whereas at the Claybury Insane Asylum, out of 1,271 adult autopsies he has found only 1.8 per cent. of cirrhosis of the liver. In the asylum he has had only one case of cirrhosis of the liver with ascites, and this person had been convicted 400 times in the criminal courts before having been declared insane.

Among the hospital patients, on the contrary, there were many cases of cirrhosis of the liver with ascites. Mott therefore comes to the conclusion that a person who can drink to a condition of advanced cirrhosis of the liver has inherited an inborn stable mental organization. Such individuals he finds may exhibit no previous mental symptoms beyond a weakened will and a loss of moral sense. He says there can be no doubt that neurasthenics, epileptics, imbeciles, degenerates and potential lunatics possess marked intolerance for alcohol, and failure to discriminate between what is hereditary and what is the result of alcoholism has been the cause of much confusion. Those who are alcoholics and show only weakened will-power and failing memory do not necessarily become permanently insane.

Hodge has given dogs alcohol from puppyhood to maturity in such quantities as to materially reduce their mental ability, but on the withdrawal of alcohol, normal intelligence was awakened.

Statistics have been collected which show that in the mining counties of England there is much alcoholism and little insanity, whereas in the country districts the reverse is true. The explanation given by Sullivan is that the more feeble minded among the English stay in agriculture and procreate their species, whereas the more intellectually active move to the town environment. So it may be, that perhaps no more than 10 per cent. of the insane are really produced by the direct action of alcohol, the rest having inherited conditions of weak intellectuality.

A further question is the action of alcohol on heredity, a matter which has been taken up by some of the most prominent English authorities. The question is, does parental alcoholism influence the physical and mental ability of the offspring. This question is discussed by Hyslop in a recent number of the *Lancet*. It is still doubtful whether the heritage from alcoholic parents is due to the alcoholism or whether it is due to the inherent parental degeneracy with the accompanying tendency towards alcoholism, and here again one must consider the association of the child with its alcoholic parent usually in an unwholesome poverty-stricken environment. Hodge has demonstrated that alcoholized dogs give birth to offspring of low vigor and low viability.

It is stated that the only true solution of this question in human beings is to be obtained through a number of instances in which children have been born to parents before the alcoholism, during alcoholism and after recovering from alcoholism. Such experimental conditions, of course, are not to be thought of as premeditated, and the history of such cases as actually occur in the tragedy of life are only with difficulty obtainable with accuracy. It is but recently that hereditary studies have been made on the subject of the color of the eyes, of the hair, and in other problems the work of necessity becomes more and more complicated. However, such statistics as have been collected seem to indicate that with each successive generation addicted to alcoholism there is a shorter period of existence before alcoholism sets in in the offspring. Thus Hyslop says that parental alcoholism accentuates the downward trend of an inherited neurosis and physical degeneracy.

There can be no doubt that this question of the use and abuse of alcohol is one of the most serious with which the modern world to-day has to deal.

SCIENTIFIC VERSUS PERSONAL DISTRIBUTION OF COLLEGE CREDITS

By President WILLIAM T. FOSTER

REED COLLEGE, PORTLAND, OREGON

EARLIER articles in the Popular Science Monthly and in *Science* have shown that grades in college courses have no exact meaning.[1] Yet college honors are everywhere awarded on the naïve assumption that grades in college courses are distributed on a scientific basic. For many important administrative purposes we assume that an A in one course is equivalent to an A in another course; that the 80 per cent. of one instructor indicates an achievement equal to the 80 per cent. of another instructor. Accordingly, we estimate the fitness of candidates for admission, determine eligibility for athletics, assign annually hundreds of thousands of dollars in scholarships and fellowships, award commencement honors, elect men to Phi Beta Kappa, and confer degrees wholly, or in large part, on the evidence secured by merely counting the number of As, the number of Bs, and so forth, that each student has to his credit. The question is pertinent to what extent our assumption of the equivalency of grades is warranted by the facts.

Our universities and colleges vary so little in this phase of the administration of the curriculum that the detailed distribution of the grades of a few institutions for a few years will fairly represent the practise, except in two or three universities, throughout the country. The grades A, B, C, D usually represent degrees of excellence between 100 per cent. and 60 per cent. of some undefined thing and are all pass marks. The grade E commonly indicates failure. In the figures here presented, the grades have these meanings. The per cent. of the students in each subject who receive each grade is graphically shown, so that a glance reveals the central tendency for each grade in each institution and the extreme deviations in both directions. In all cases the names of instructors and the exact designations of the courses are omitted, at the request of the several institutions concerned; though one may be pardoned the query, what objections could there be to publicity, if grades were distributed on a defensible basis.

Figs. 1 and 2 show the proportion each grade is of the whole number given at Harvard College in each of the elementary courses in twenty-one subjects during one academic year. Thus, the range of the highest

[1] Popular Science Monthly, Vol. LXVI., pp. 367–378, 1905, by J. McKeen Cattell. *Science*, N. S., Vol. XXVIII., No. 712, pp. 243–250, 1908, by Max Meyer.

TABLE I

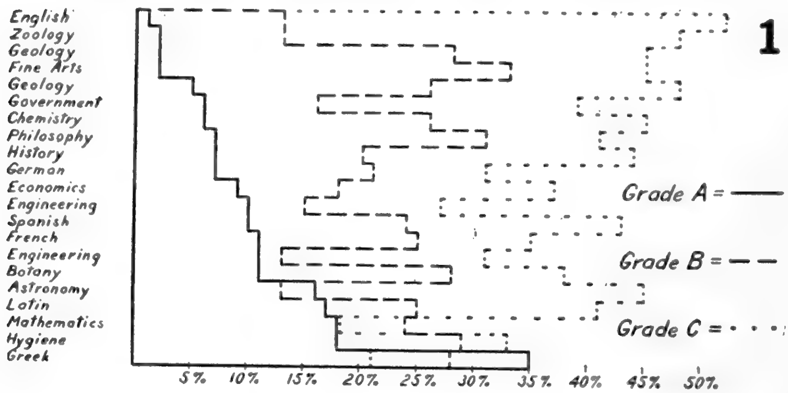
HARVARD COLLEGE

Distribution of 8,969 Grades, Elementary Courses

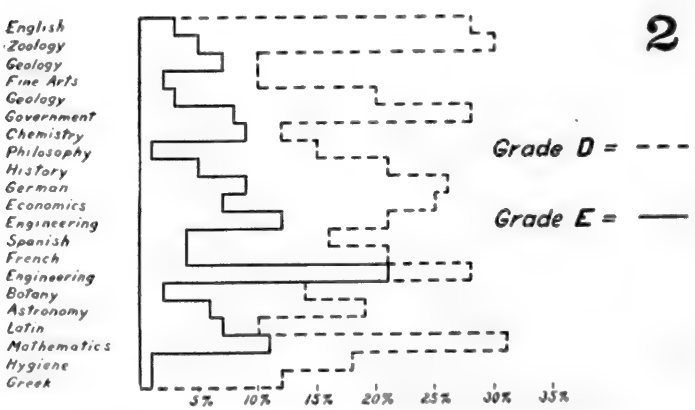
Group 1	% A	% B	% C	% D	% E	% Abs.	Total
Astronomy	16	13	45	19	6	1	69
	10	17	48	17	7	2	130
Botany	11	28	38	14	2	7	183
	4	32	44	13	½	6	219
Chemistry	6	26	45	12	9	2	334
	8	19	45	17	11	0	319
Economics	10	18	37	25	7	3	531
	7	19	43	21	7	3	436
Engineering	11	15	31	28	12	3	114
							121
Engineering	10	13	27	21	21	9	139
							129
English	1	13	52	28	3	3	603
	1	11	51	32	3	3	564
Fine Arts	2	33	45	10	2	9	58
	6	27	67	0	0	0	49
French	11	25	35	21	4	4	156
	12	19	36	19	10	4	145
Geology	5	26	45	20	3	2	489
	5	25	33	28	2	7	85
Geology	2	28	48	10	7	5	122
	4	20	43	24	7	2	108
German	7	21	31	26	11	4	259
	6	14	32	27	17	2	293
Government	6	16	39	28	8	3	356
	9	23	37	21	7	2	419
Greek	35	28	21	13	1	3	72
	15	36	34	7	5	3	61
History	7	20	44	21	5	2	347
	7	24	42	20	6	2	380
Hygiene	18	29	33	18	1	0	87
	8	23	48	14	4	3	139
Latin	17	25	41	10	7	0	143
	15	27	41	5	10	2	128
Mathematics	18	24	18	31	11	0	85
	14	22	31	23	11	0	95
Philosophy	7	31	41	15	2	5	229
	7	23	61	8	0	½	215
Spanish	10	24	43	16	4	3	106
	7	13	38	33	8	2	119
Zoölogy	2	13	48	30	5	1	149
							184
Average	7	20	42	21	7	3	213

credit (A) is from one per cent. in English to thirty-five per cent. in Greek. The range of grade B is from eleven per cent. in English, zoology, engineering and astronomy to thirty-three per cent. in fine arts. Grade C shows a minimum of eighteen per cent. in mathematics and a maximum of fifty-two per cent. in English. Grade D ranges from ten to thirty-one; grade E, from one to twenty-one. Courses with fewer than one hundred students are omitted, as the smaller courses are not fairly comparable in a single year with the larger ones on a percentage basis.

Still further to safeguard our comparisons, the intermediate and advanced courses are grouped by themselves. Some men believe that the credits in an advanced course, which to some extent represents the survival of the fittest students in the department, should be differently distributed from the credits in an elementary course in the same subject. College records everywhere show that a larger proportion of the



high rank men than of the low rank men, in an introductory course, continue the subject in advanced courses. Indeed, one of the chief objects of the elective system is to enable students to specialize in fields in which they are likely to achieve distinction. But this hardly justifies the extreme and continued variations among the grade distributions of the intermediate group of courses, nor does it account in a sat-



isfactory way for the diverse practises among advanced courses. Figs. 3 and 4 show a variation of two per cent. to sixty per cent. in the As given in intermediate courses in Harvard College; and extremes of seventeen per cent. and seventy-four per cent. in the case of grade B, Fig. 4 pictures the statistics of grades C, D and E.

Table II. indicates the comparative distribution of grades A–E for the three groups—elementary, intermediate and advanced.

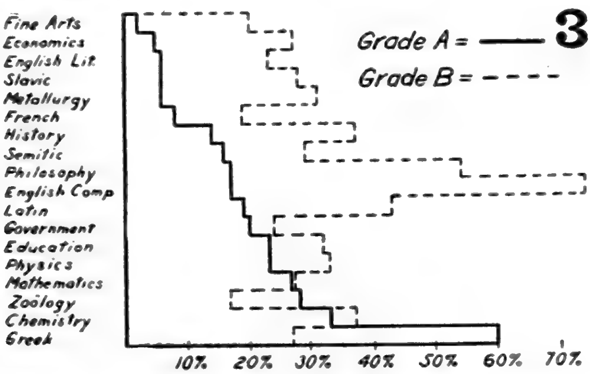
TABLE II

HARVARD COLLEGE

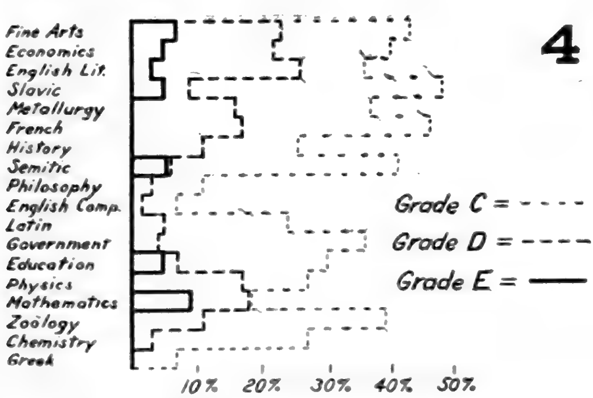
Distribution of all Grades for Two Academic Years

Totals	% A	% B	% C	% D	% E	No. of Grades
Group I.	7	20	42	21	7	8,969
Group II.	12	28	37	13	4	2,456
Group III.	36	38	13	2	2	476

Not only are there extreme variations among different courses, but there are variations in the same courses from year to year that can not be accounted for, apparently, by any of our scientific studies in the



distribution of abilities among human beings. Fig. 5 shows the per cent. of As and the per cent. of Bs given in each of 53 courses at Har-



vard College for 1906–07 contrasted with the same data concerning the same courses for the following year. The data are taken from the published rank lists and from the enrollment in courses as given annually in the president's reports. A glance at the graphs in Fig. 5 reveals the fact that eight or ten courses show marked changes from one year to the next, whereas in eighty to ninety per cent. of the courses there are only negligible variations.

Another fact revealed in Fig. 5 is worth noting here. The six courses reaching highest in the A group are as follows: courses in Greek,

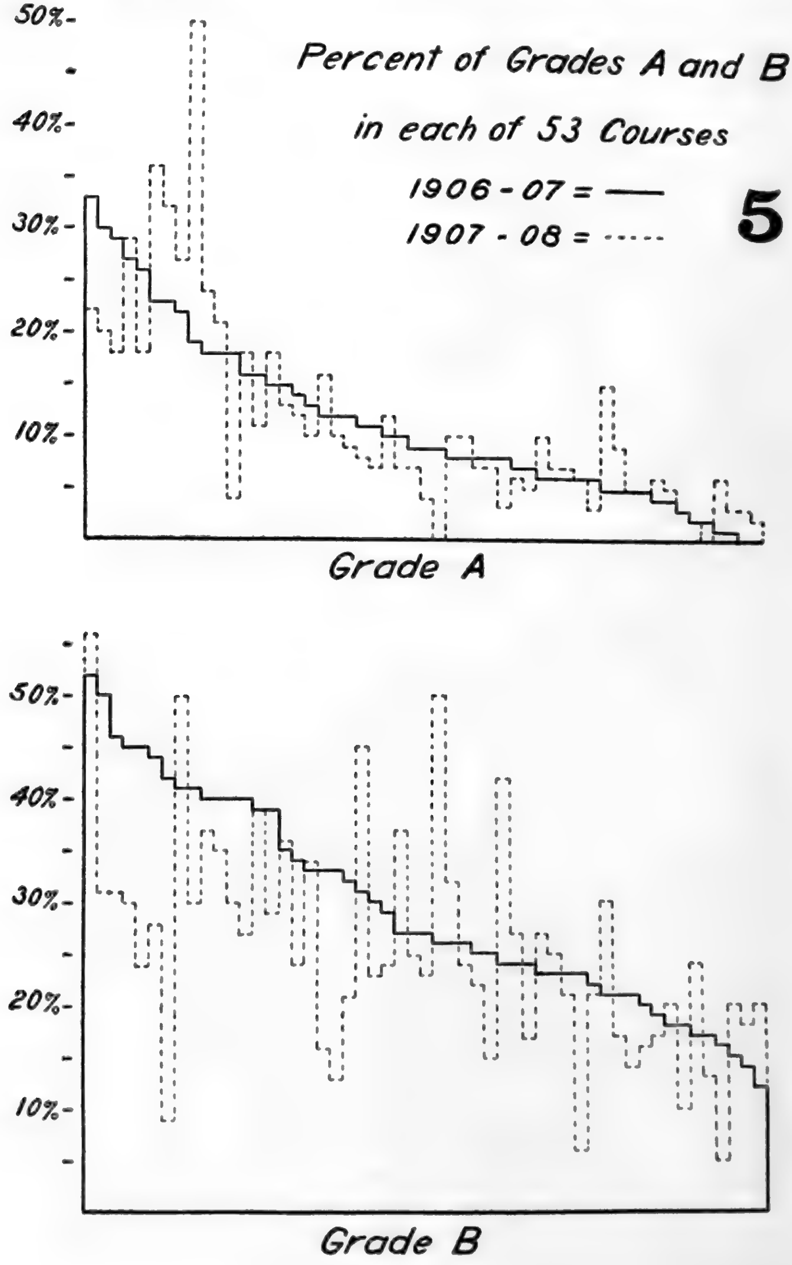
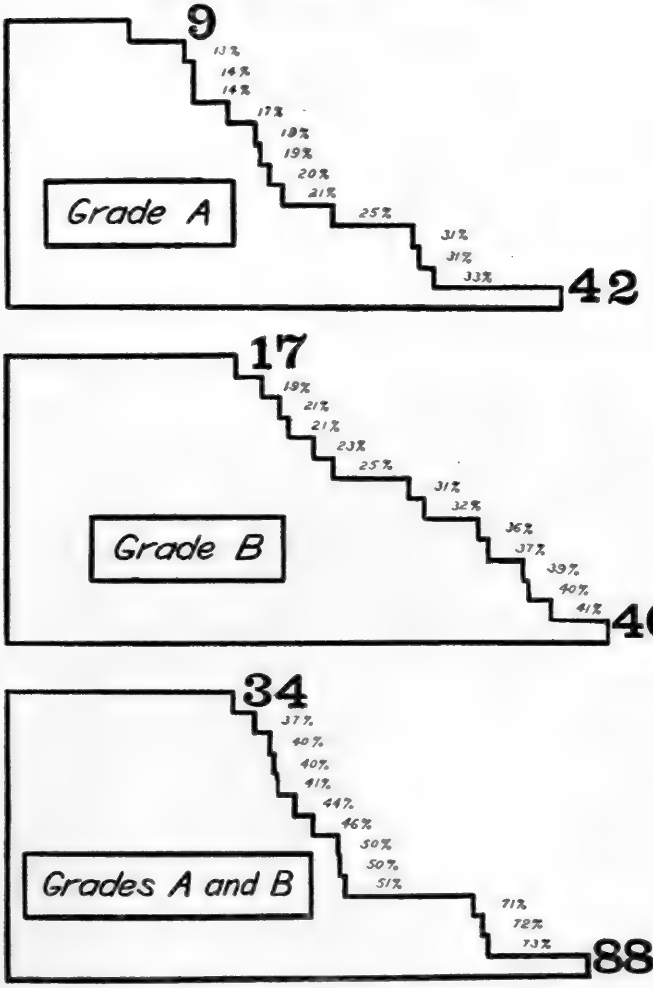
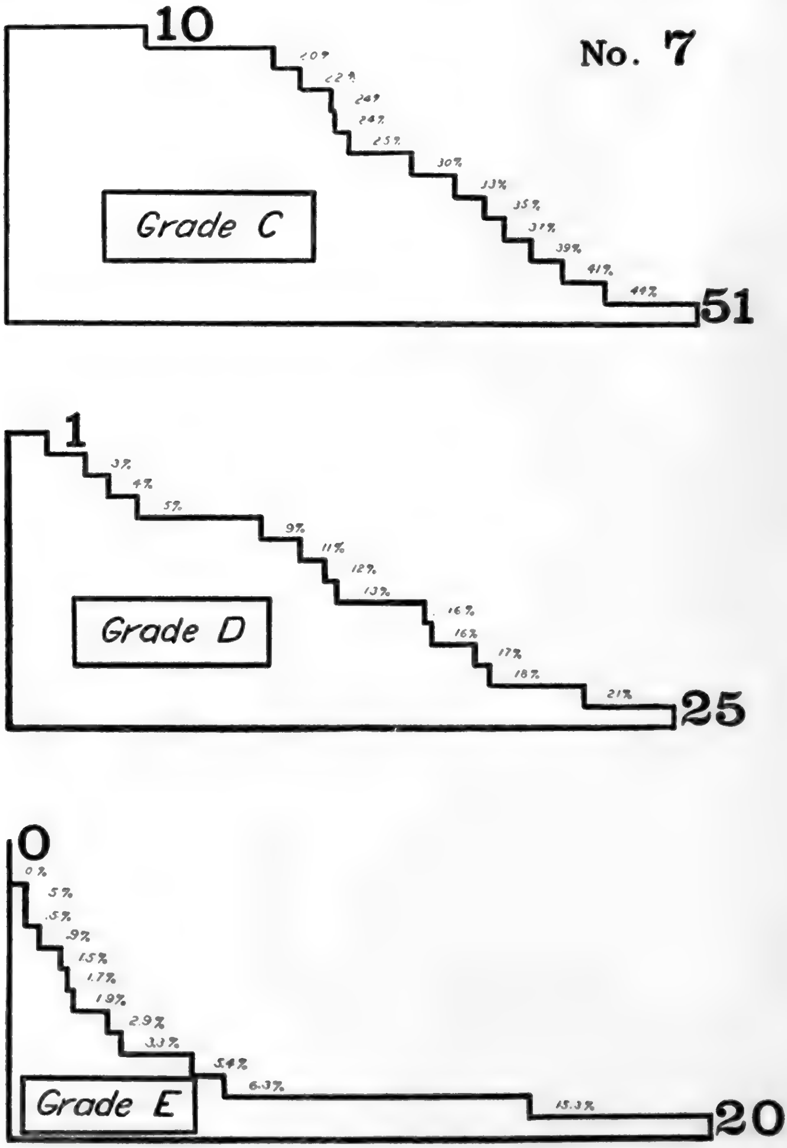


Figure 6 Showing Percentages of Various Grades in Total Grades of each Instructor having over 100 Students



Greek, Italian, Greek, Greek, Latin. The exact designations are withheld because of the respect of the administration for the feelings of individual instructors. Nevertheless, students are encouraged to examine the published rank lists, in which he who runs for high grades may read his chances. Reference to Fig. 1 shows that in 1903–04, as well, Greek far surpassed all other subjects in awarding high marks.

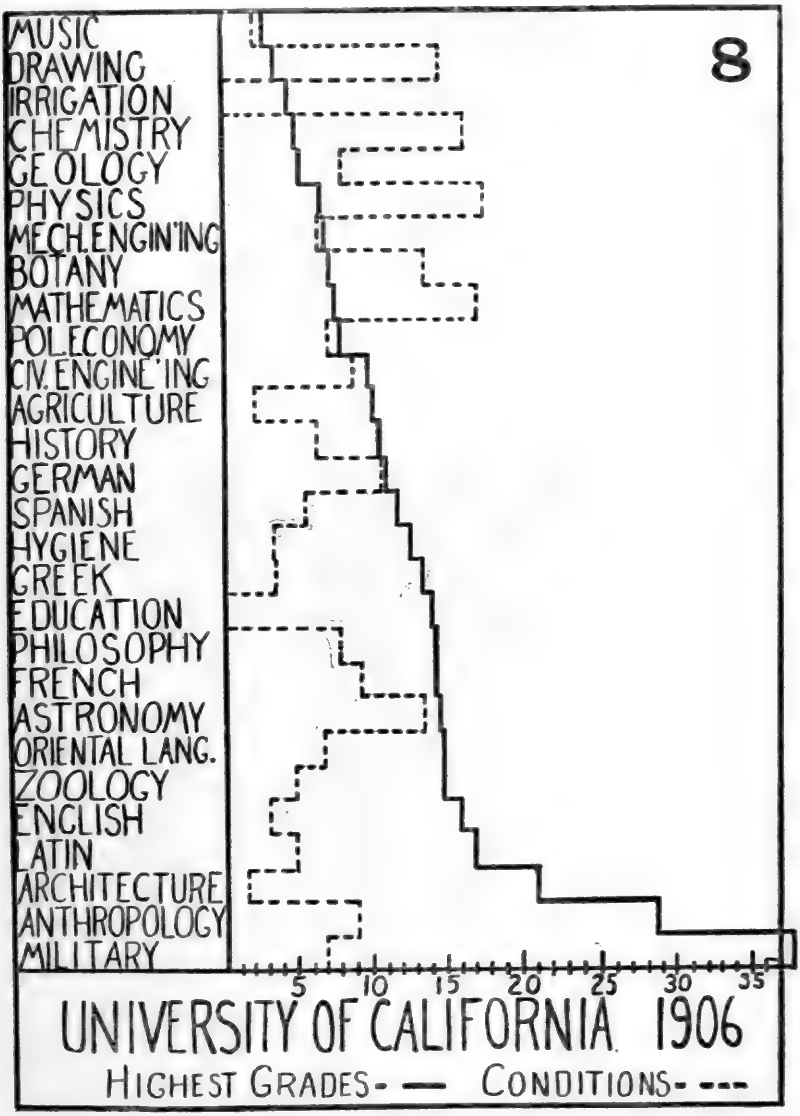
Figs. 6 and 7 show the range of percentages for each grade, A–E, for each instructor in Bowdoin College, Maine, giving in 1907–08 over one hundred grades. Fig. 8 gives the distribution of highest grades and of lowest grades, the honors and the failures, for various departments at the University of California in December, 1906. It is unnecessary to present statistics for other years or for other institutions. From Maine to California the administration of college credits, though



alike in no other particular, agrees in this—that its basis is personal rather than scientific.[2] We do not know what the symbols mean: they

[2] W. F. Dearborn, in Bulletin 368 of the University of Wisconsin, presents numerous unscientific distributions of grades in Wisconsin.

have no defined meaning. To reply that a given symbol signifies a certain per cent. of an undefined something is to beg the question. The administration of the curriculum on a percentage basis—giving grade B in Greek, for example, a value of 80 to 90 per cent.—is apparently exact, but in reality far from it.



We have here used the statistics of institutions which do not attempt to grade students in many groups. The usual school method of grading on a one-hundred-per-cent. basis produces confusion. As a matter of fact, teachers can not use more than a dozen grades with discrimination.

This has been proved repeatedly by careful tests, and is evident from the erratic clustering of grades around arbitrary points on the scale in every school where the attempt is made to use a scale with thirty or more divisions.

Individual instructors, in defense of their extreme variations from the mean proportion of high and low grades, often assert that the students who elect their subjects are much better than the students who elect other courses. Figs. 2 and 8 seem to indicate that quite the opposite is the truth. The poorer students elect a larger proportion of their work than the better students from courses in which the number of *high* grades given is relatively large. The better students elect a larger proportion of their work than the poorer students from courses in which the number of *low* grades given is relatively large. Furthermore, it is possible to show that the variations in grade distribution do not represent equal variations in the abilities of the groups of students concerned. We can demonstrate this by comparing the grades attained by a large number of students in certain departments with the grades attained by these *same* students in other departments.

Such a study is summarized in Table III. It exhibits the record in Harvard College of 363 men from twelve classes who later graduated with honor from the Harvard Law and Medical Schools. It gives the exact number of students receiving in a given subject a rank higher than their median rank for all subjects. Thus it appears that English, fine arts, mathematics, classics and modern languages, in the order named, constitute a group in which the grades assigned in this institution are comparatively low. On the other hand, natural sciences, philosophy and history and political sciences, in the order named, make up a group in which the grades assigned are comparatively high. At the two extremes stand English, in which 86 per cent. of the students received lower than their median rank in all subjects, and natural sciences, in which 71 per cent. of the *same* students received higher than their median rank. Furthermore, this table does not represent the extreme variations within departments. The eccentricities of the hardest markers in English and the easiest markers in natural sciences are here offset by the other markers in each department. We must conclude, therefore, that the diverse distribution of grades shown in the figures can not be justified by the unsupported assertion that the students electing certain subjects have far more ability than the students electing other subjects.

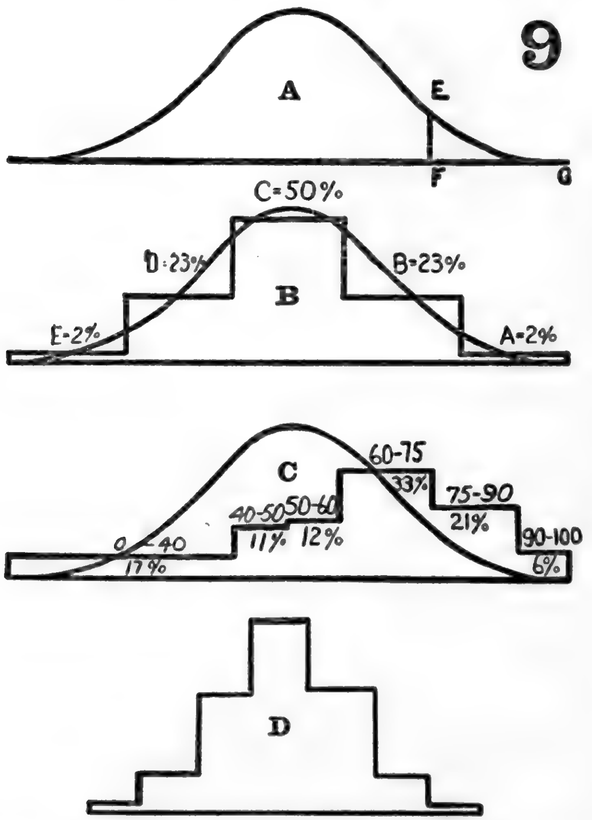
The question arises whether it is possible to supplant the personal equation as the chief factor in the awarding of college grades by scientific guidance? The immediate answer to this question depends on whether the distribution of mental traits in groups of individuals follows any regular law—and for the present on nothing else. The ultimate answer to this question will be the discovery of units of measurement in every school subject, and the construction, by scientific methods, of scales that can be applied as the foot-rule is now applied, regardless of time, or place or persons. The best possible ratings of individuals by relative position are only temporary expedients that must some day give way to ratings by means of standard scales. The nearest approach to such a scale, and a perfect illustration of the method, is E. L. Thorndike's "Handwriting," *Teachers College Record,* March, 1910. The Courtis Standard Tests in Arithmetic also furnish a means of comparing the achievement of one school with that of another, and the work of one year with that of another. We are not likely to continue to spend billions of dollars on education and be satisfied with guessing at results. Measurements of results with quantitative precision will be made as soon as people know enough to demand such measurements.

Lacking the necessary units and scales, we may even now ask whether the differences among individuals in mental capacities are explainable by any simple causes and amenable to any single type of description. They are not, if we are to accept the tables and figures just presented as correct records of the abilities of college students. But fortunately we are not dependent on such unscientific data. Psychologists have recently given us many rigorously scientific studies of the distribution of mental traits.

These studies have shown that in any group of individuals representing a single species, the distribution of any trait not greatly influenced by natural selection appears to be that of a chance event. The surface of frequency for that trait approaches that of the probability integral. It is like the cross-section of a pile of sand dumped from a cart. The most convenient way to represent tables of frequencies is by means of diagrams in which distances along a base line represent the different quantities, or units of measurement, and the heights of columns erected upon it represent the frequencies of the several quantities. Fig. 9 presents several illustrations, *D* representing the results of a memory test. By such graphic representations rather that algebraic formulæ, the answer to our question and the evidence for it can be made clear even to one unfamiliar with the mathematical properties of the surface of frequency of a chance event.

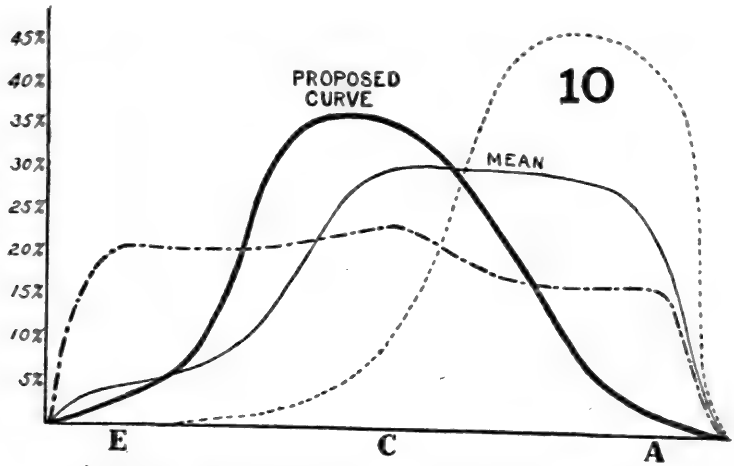
Fig. 9, *A,* gives the distribution, or surface of frequency, of the type to which we assume that all distributions of mental traits conform. Fig. *B* is the same type of distribution with a coarser separation into grades. This type is called the normal surface of frequency. It describes, for example, the distribution of accidental errors in scientific observation. Thorndike's numerous measurements show a remarkable uniformity in the distribution of mental traits among individuals. Fig. 9, *D,* showing the memory span for digits in 123 American women students, is a good example. In all cases the distribution closely approximates the normal type.

Does the distribution of the complex abilities that determine excellence in college courses approximate this normal type? Theoretically it should, and our theory is supported in a striking way by the distribution of 8,969 grades in twenty-one elementary courses for two years, 1907–08, at Harvard College. The curve in Fig. 11, representing this distribution, is nearly normal. The percentages for the grades A–E are, respectively, 7, 20, 42, 21, 7. Yet there are wide variations among



the instructors in these very courses. In fact not a single instructor came as near to a normal distribution as the sum of all their grades. Now, no one of these markers is as likely to tell the truth as all together. Their several errors correct each other and thus give us, in Fig. 11 (Group 1), a close approximation to the type of curve we should expect to have with an infinite number of cases. In 1909–10, the grades in certain elementary courses in Harvard College (Chemistry 1, Comparative Literature 1, English A, Government 1, History 1, Mathematics F, Philosophy C, Zoology 1) were distributed in the following percentages: A = 5.5, B = 21, C = 44, D = 19.5, E = 9.

The curve for these facts was printed and sent to each instructor with an explanation of its meaning, and a superimposed red curve showing in each case precisely how the instructor's distribution differed from the norm. A table was prepared showing the distribution of grades for all courses having 80 or more students.[3] The range for each grade in per-



Mean and Extreme Distributions of Grades A-E

Total Grades = 2757 Mean Distribution = —— Extreme Distributions = - - -

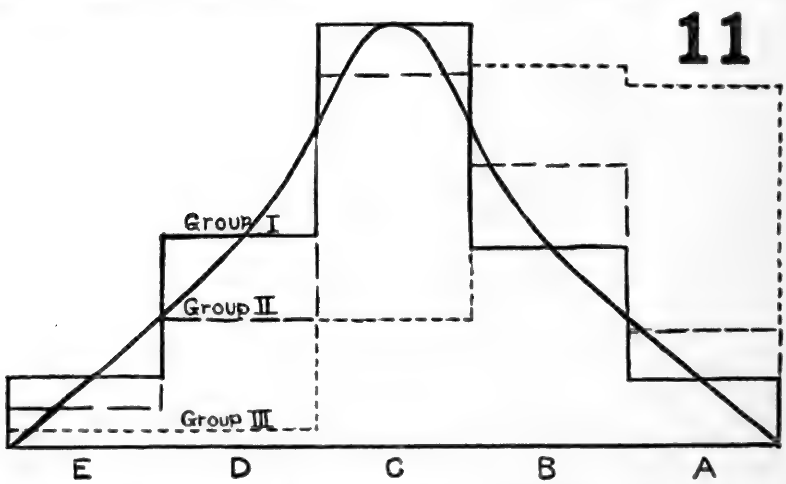
centages was as follows:

A	0.7–20
B	6–39
C	27–62
D	0–31
E	0–20

Accordingly, we have scientific grounds for assuming that a theoretically correct distribution of the grades of college students will approach the normal surface of frequency (Fig. 9, *A* and *B*) unless the group is subject to selection. In that case the curve would be skewed negatively or positively as in Fig. 10.

[3] In Bulletin 368 of the University of Wisconsin, Professor Dearborn attempts to justify the normal distribution of grades "from the fact that it is used in actual practise." Two objections may be made to this contention: first, very few instructors do closely approximate the normal distribution; second, as their practises have no scientific basis, any one of them could only by accident indicate the theoretically correct distribution. If, however, all of Professor Dearborn's curves were represented by one, made from thousands of grades by scores of instructors, it would conform more closely to the general biological law of variation than any of the curves he presents.

As a matter of fact, college students are a selected group.[4] If the surface *A* (Fig. 9) represents the distribution of all elementary school pupils at a given time, then most of those pupils who are to go to college fall in the upper end of that surface. If our colleges took the best students and only the best, if they made a clean cut off the top, then the distribution of their abilities would be represented by a surface closely approximating *EFG* of surface *A*. But for various reasons —including our extremely inaccurate means of attempting to determine fitness for entrance—our colleges do not admit merely those who are best fitted to pursue higher study, that is, the upper end of the



surface. Some pupils find ways into college who occupy stations in the surface not far above the median; or the line of mediocre ability. This is clearly shown in Professor Dearborn's study of the relative standing in scholarship of students in high school and in college. Consequently the lower end of the surface would not be clean-cut as in *EFG*, but rather like the heavy line of Fig. 10. It would, of course, be skewed positively, for there could not possibly be many cases near *G*. Most of them would have to fall in the larger space near *EF*. The curve would be similar to that for incomes. The heavy line in Fig. 10, therefore, though not representing with precision[5] the scientifically correct distri-

[4] Thorndike, E. L., "The Selective Influence of the College," *Educational Review*, 30, 1.

[5] "The curve of probability gives us the only precise meaning of the term 'scientific knowledge.' We have seen that human observations and measurements are never precisely accurate. Generalizations, in like manner, are never precisely true. The formulation of a law of nature can never be made absolutely exact. Scientific knowledge, therefore, is not that absolutely exact and certain knowledge which the popular mind assumes it to be. It is certainty or exactness within a range of error, and to diminish that range is the object of scientific endeavor." Giddings, F. H., "Sociology," Columbia University Press, New York, 1908, p. 24.

bution of college grades, does certainly come nearer the correct frequency curve than the normal curve, or than that representing the present practise of any college or university in the country. In institutions where many sons of rich parents are dragged just above the failure line by tutors, the curve would be skewed even more than in Fig. 10.

As we proceed upward through the years of school and college we should thus expect to find the curve skewed more and more in a positive direction, provided the standards are appropriately higher each year and a new base line is taken for each successive group. Those who accept the principle of normal distribution only for freshman courses in college, or for any single period in the school life of the child, would be at a loss to prove its peculiar fitness for that period.

TABLE III

RECORDS IN HARVARD COLLEGE OF 363 HONOR GRADUATES IN LAW AND MEDICINE

Number of Students receiving Grades in Certain Departments ABOVE their General Average in all Departments

	Fine arts	Natural sciences	Mathematics	Philology	History	Modern languages	English	Classics
Law graduates	24	68	33	78	86	67	12	41
Medical graduates	32	88	36	53	42	50	12	24
Total	56	156	69	131	128	117	24	66

Number of Students receiving Grades in Certain Departments BELOW their General Average in all Departments

	Fine arts	Natural sciences	Mathematics	Philology	History	Modern languages	English	Classics
Law graduates	40	55	33	32	29	84	46	41
Medical graduates	45	19	48	33	53	55	109	32
Total	85	64	81	65	82	139	155	73

Summary

Number above	56	156	69	131	128	117	24	66
Subject	Fine arts	Natural sciences	Mathematics	Philology	History	Modern languages	English	Classics
Number below	85	64	81	65	82	139	155	73

At least two institutions now enforce a distribution of grades on a scientific basis. At the University of Missouri, an A is approximately equal to an A, a B equal to a B, in a defined sense; so that grades may be intelligently and fairly used for administrative purposes. According to the definitions adopted in June, 1908, grades A + B must equal

25 per cent., grade C, 50 per cent., and grades D + E, 25 per cent. of the total number given by each instructor. Under the old system, forty teachers in five years graded their students so that 25 per cent. received A, 35 per cent. received B, and 32 per cent. received C. Moreover, the lack of uniformity among instructors was as great as at Harvard and California. Under the new system the irregularity of the grading was reduced the first year from one fourth to one tenth, or in the ratio of 5 to 2.

The distribution of 24,979 grades in percentages was as follows:

	Aug., 1908	Feb., 1909	June, 1909	Feb., 1910	
B	23.3	20.7	21.0	21.3	26.0
A	7.7	4.6	4.6	4.7	
C	41.2	47.5	48.8	49.6	
D	8.7	13.7	13.8	14.4	20.9
E	15.6	8.5	8.0	6.5	
Delayed	3.5	5.0	3.8	3.5	

Not counting the delayed reports, the distribution of the 11,342 grades for the first year of the new system was, in percentages:

A	4.9	26.6
B	21.7	
C	50.0	
D	14.5	23.5
E	9.0	

In spite of the adopted definitions, the tendency remains to mark students too high. Every attempt to devise a system of marking whereby extraordinary achievement can be awarded the distinction it deserves has failed because of the democratic tendency in all institutions to place so large a proportion of students in the "distinguished" group. At Dartmouth College, a professor once announced to a large class, "Gentlemen, I must warn you that the committee on instruction has requested me to make my examinations harder, but, gentlemen, I am pleased to say that I shall continue to mark the papers." A century ago a Virginia academy attempted to have its students graded in six divisions,—*bonus, melior, optimus, and malus, pejor, pessimus.* But history records that "the continual tendency was to mark inferior students too high. Thus it came to pass that not half the bad scholars got *malus,* the worst almost never fell below it, and *bonus,* though a mark of approbation, came to be considered as a disgrace, while *optimus,* which ought to have been reserved for scholars of the highest merit, was commonly bestowed on all who rose above mediocrity." As the president of this old institution remarked, "a temporizing professor who loves popularity, and desires, like the old man in the fable, to please everybody, is sure to be guilty of this fault, and like many a politician, to sacrifice permanent good for temporary favor." This is still the tendency everywhere, in spite of the manifest absurdity of declaring a large proportion of students distinguished.

On the other hand, nearly every institution has instructors who occasionally refuse pass marks to large proportions of their students. It was when a professor in Missouri "flunked" his entire class, and the boards overruled him by passing the entire class, that some of the faculty urged the adoption of a scientific system of grading. The students at another college put more sense than lyrical charm into the following lines:

> There was a professor named Bray
> Who forgot the reflection on Bray,
> When in two of his classes
> He gave but few passes,
> And frightened good students away.

If an instructor refuses to pass some of the median half of the surface of distribution, it must mean, as a rule, that his methods of instruction or discipline are faulty, or that an unwarranted proportion of students have been admitted to a course they are unprepared to take. In either case, the fault is not with the students, but with the administration of the college.

The distribution of grades by the various departments at the University of Missouri in 1909, under the new rules, showed a range in percentage of A's from twenty in the history of art to zero in political science. The narrow limits of 2 to 7 per cent. included seventy-two per cent. of the departments. Thirteen departments gave the median percentage of A's, which was 4. The entire distribution of grades by departments was published and sent to the instructors, together with a table locating the responsibility for the failure to hold to the adopted definition of grades. The table gave the name of each instructor whose percentage of A–B grades differed from 25 by more than 2, and the name of each instructor whose percentage of D–E grades differed from 25 by more than 4. The table would have been an invaluable guide to students who were seeking the easiest way to get high grades. It was in fact a table of chances.

As a result of this wholesome publicity, the instructors in 1910 showed an even closer approximation to the adopted scheme of distribution. This means that we come nearer to knowing what a grade stands for at the University of Missouri than at any other institution in the country.

Replies from 58 members of the faculty of the University of Missouri in 1910 show that 51 approve of the general principle of standardizing grades and 4 do not approve; only 1 reports that he does not aim to have his grades conform to the system in the long average; 21 tend in grading large, elementary classes to give low marks and offset them by higher marks given to advanced classes, 20 do not; 15 think that the effect, before the semester is over, is to discourage the efforts of some students appreciably, 23 do not; 26 believe that the effect of the system has been good, 7 regard it as bad, and 23 as inappreciable.

TABLE IV

UNIVERSITY OF MISSOURI

Distribution of Grades, 1910

Subjects of Study	% A	% B	% C	% D	% E	% Del.	Total
Class. Arch. and History of Art	15	25	39	9	4	8	297
Botany	9	19	44	16	10	2	557
Physical Education	8	17	50	10	15	—	649
Latin	7	25	45	18	5	—	323
Germanic Languages	7	23	45	13	9	3	1006
Animal Husbandry	7	22	51	14	4	2	594
Economics	7	15	43	23	11	1	369
Agronomy	6	26	57	4	6	1	321
Horticulture	6	23	47	13	8	3	495
Music	6	20	58	4	11	1	280
Law	5	24	52	10	2	7	3984
Experimental Psychology	5	20	53	14	7	1	497
Mathematics	5	20	49	12	11	3	962
Philosophy	5	14	45	20	12	4	336
Veterinary Science	4	27	59	7	2	1	292
History	4	26	49	13	5	3	1023
Sociology	4	23	51	16	5	1	594
Education	4	22	50	16	7	1	751
Journalism	4	21	59	12	3	2	342
Political Science	4	21	44	22	3	6	280
Philosophy of Education	4	20	53	19	3	1	365
Home Economics	4	20	53	15	2	6	220
Physics	4	20	43	19	8	6	1030
Electrical Engineering	3	22	49	18	4	4	491
Mech. Draw. and Hydr. Engin.	3	22	49	12	8	6	726
Mechanical Engineering	3	21	53	16	6	1	642
Romance Languages	3	21	49	14	10	3	468
Shopwork	3	20	59	12	3	3	376
Theory and Practise of Art	3	19	48	15	9	6	289
English	3	18	50	18	8	3	1583
Chemistry	3	16	46	20	12	3	1379
Elocution	2	25	50	21	2	—	232
Civil Engineering	2	21	52	18	5	2	836
Zoology	2	19	49	20	8	2	391
Geology and Mineralogy	2	17	57	16	6	2	344
Military Education	2	16	52	6	—	24	293

Discarding the arbitrary divisions employed wherever undefined symbols and numbers are used, we may divide the area of the normal surface of frequency as it is always divided for other scientific purposes. We may mark off a middle area equal to the sum of the two areas left at the sides. Half the students of any group will be represented by this middle area. We may designate this group by the symbol C, or K, or 75, or 13, or 289, or we may name it after the chairman of the school board. Much will be gained when we rid ourselves of the notion that the letters and numbers we now use so widely necessarily have any particular meaning. What we call this group does not matter: the significant thing is that it stands for an ability above and below which half the cases lie. It means that a student taken at random from a class of one hundred has one chance in four of falling above the middle group. It means that if we represent the ability of this group by C, we know precisely what an instructor means when he gives a student that grade. He means that the ability of the student in his course is greater than that of one fourth of the course and less than that of another fourth of the course. This median group ought to be the largest, for it is where most human beings fall, as shown by the height of the probability curve.

We can not indicate real distinction, however, unless we subdivide the upper quartile. We can do this arbitrarily or we can turn to a table of values of the normal probability integral.[6] Here the extreme ability is called 3. The point of the vertical line which separates the median group from the inferior group is .68. Half way between 3 and .68 is 1.84. Accepting this as the division point for the upper and the lower quartile, we find at the upper end of the surface of distribution three per cent. of the whole, and at the lower end three per cent. If we indicate the five sections, from the upper end to the lower, by the symbols A, B, C, D, E, we have the following distribution of grades:

	Per Cent.
A	3
B	22
C	50
D	22
E	3

If, on the other hand, we assume that the distribution of abilities of college students is not normal, but skewed, the following percentages for each grade would more nearly represent the facts:

	Per Cent.	
A	2	20
B	18	
C	50	
D	24	30
E	6	

As variation in the abilities of those who elect a given course is sure to occur from year to year, some would prefer an elastic definition of the grades; for example:

	Per Cent.
A	0– 6
B	15–21
C	45–55
D	20–28
E	0–10

[6] A table of values of the normal probability integral is found on page 148 of Thorndike's "Mental and Social Measurements." In *Science*, 712, 243, Max Meyer uses this basis for dividing the probability surface.

Any one of these definitions of the meaning of the five groups would come nearer to telling the truth, be more serviceable for administrative purposes, and convert the vast amount of labor now used in making out grades into more valuable data for the scientific study of education than the present personal distribution of college credits. A defensible definition of grades should be adopted by each faculty and its members should be required to adhere closely to it, in the long run, at least in all courses primarily for undergraduates, until we can supplant the method of grading by relative position by scales made up of equal units.

After the definition of grades is adopted, a table should be sent to each instructor, as often as grades are required at the college office, showing the distribution of grades in each course in the college and emphasizing those that depart far in either direction from the adopted mean. Every instructor should be requested to justify his eccentricities, at least in a series of years. If such publicity does not accomplish sufficient uniformity for administrative purposes, insurgent and careless instructors should be reminded by the appropriate authorities that it is for the interest of all for each to abide by the decision of the faculty.

To rate instructors solely with respect to the proportion of high grades awarded by them, or solely with respect to the quality of students attracted to their courses, is evidently inadequate. An instructor may give more high grades than his associates, because he has more students who deserve distinction. But if this is the case, the administrators of the college curriculum can readily devise a means of measurement which will show at a glance the justification for any *conspicuous* deviation from the normal distribution of grades. All the instructors of any institution may be located on a scale which shall take account not only of the grades awarded, but as well of the quality of the students electing each course.

For example, as part of an investigation conducted at Williams College by a committee in accordance with a resolution of the faculty, Dean Ferry, at the request of the president, devised a plan for measuring the relative quality of the classes in the elective courses of junior and senior years and of the grades given in each. Taking the work of the first two years, where the courses are nearly all prescribed, as a basis for the determination of the scholarship of the students, statistics were carefully worked out for the elective courses of three successive classes. The results of his extensive study are summarized in Table V. Column I. gives each instructor his position with respect to the quality of students in his courses. The larger the proportion of men attracted to his courses from the upper half of the student body in general scholarship, the larger the plus rating of the instructor. For purposes of comparison, Column II. gives each instructor his position with respect to the proportion of high grades and low grades assigned to him. Thus, for example, instructor number 4 has the high rating of 41 in the quality of his students and the low rating of — 23 in the assignment of grades. Instructor number 26, on the contrary, has the low rating of — 21 in quality of students and the high rating of 52 in grades assigned. In other words, he has a conspicuously large proportion of the students whose general scholarship is low, and to these poor students he awards a conspicuously large proportion of high grades. Many a teacher would be surprised to discover his standing on such a scale, and the college administrator who undertakes to deal with such discrepancies, through discussion with individual members of the faculty, will do well to provide himself with a quantitative presentation of the facts.

TABLE V

A Rating of Elective Classes in Williams College

	I	II		I	II
1	113	0	16	2	41
2	113	0	17	1	42
3	77	27	18	— 1	56
4	41	—23	19	— 2	6
5	39	23	20	— 4	—11
6	39	—21	21	— 5	89
7	24	3	22	— 7	63
8	20	49	23	— 8	59
9	17	50	24	—14	40
10	15	34	25	—17	95
11	13	20	26	—21	52
12	9	41	27	—22	89
13	7	32	28	—30	114
14	6	58	29	—33	66
15	5	63	30	—40	73

Such regulation will be resented by many college teachers as an infringement on their rights. But academic freedom that allows each member of a faculty to do as he pleases in matters that reach far beyond the interests of his own department is intolerable license. As President Eliot has said:

> A faculty can properly criticize the results of any professor's, or other instructor's, work as they appear in certain easily visible ways. Among such visible evidences are . . . the resort of obviously incompetent or uninterested students to nis courses; examination papers of a trivial or pedantic sort; uniform high grades or uniform low grades returned by the professor; an extraordinary number of distinctions earned in his courses; or an extraordinary number of rejections and failures. These are legitimate subjects of inquiry by a faculty committee or by faculty officials, and can be dealt with by a faculty without impairing just academic freedom. The knowledge that this power of revision resides in a faculty is a valuable control over individual eccentricities.

It is sometimes said that "there are usually some courses in a university which, from year to year, secure only an inferior grade of pupils, and other lines of work which, for various reasons, secure a disproportionate number of superior students. Classical students in the high school and university, and students in the advanced courses in mathematics, are often examples of such selected groups of students. The above principle would not be equitable in these cases." In answer to this argument, it should be noted, first, that it is, in large part, the very grading to which objection is raised that has caused the resort of poor students to certain courses; and, second, if the better men do resort in larger proportions to certain courses, that fact can be readily shown by statistics. It is one of the many educational questions on which speculation and opinion are quite out of place.

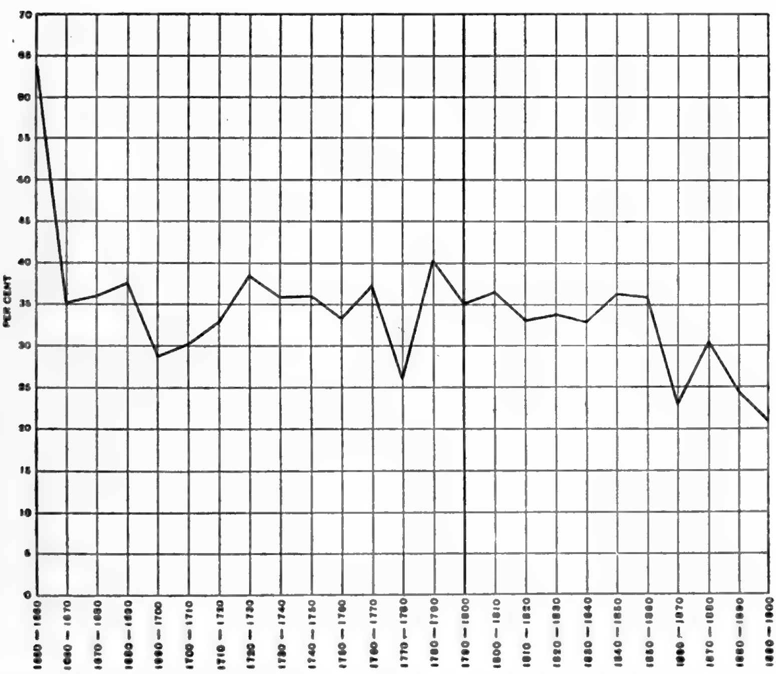
Without a scientific administration of college credits, the other safeguards of the elective system are insufficient. There will always be students who are more interested in getting through their courses than in getting profit from them. The poorer students seek the courses which give the larger proportions of high grades. Earnest but needy students, too, are under great temptation to elect courses with a view to winning money scholarships, as long as scholarships are awarded on the false assumption than an A is equal to an A. To all students who are prompted by unworthy motives in the election of studies, Figs. 1 to 11 are charts pointing the easiest courses to a degree. And students in all colleges are guided by such charts, more or less accurately plotted. It is futile for the authorities to try to suppress such information and protect their instructors from the notoriety they deserve. Nor is the elective system to blame for the presence of snap courses and the relative ease with which high grades are secured from certain instructors. Nor is the credit-for-quality plan to be condemned because it accentuates the evils of our marking devices. The best way to safeguard the elective system and the credit-for-quality plan against the evils here set forth is to enforce a scientific distribution of college credits.

THE PROGRESS OF SCIENCE

THE POPULATION OF THE UNITED STATES IN 1910

PRELIMINARY announcements have been made of the population of the states and of some of the cities as determined by the thirteenth census. The population of continental United States is 91,972,267, as compared with 75,994,575 in 1900, an increase of 21 per cent. This is the smallest rate of increase hitherto recorded, but is practically the same as for the preceding decade. The accompanying chart shows the percentages of increase, those prior to the first census of 1790 being somewhat rough estimates. Apart from drops at the time of the war of revolution and the civil war the percentage remained very constant for two centuries, but in spite of the large immigration it has dropped in the past fifty years from 35 to 21.

It is unsafe to make any prediction from such figures but it is clear that the increase in population has been maintained by immigration and by a falling death rate, and it is doubtful whether these factors will continue to make up for the declining birth rate. In 1820 there were 489 children under 16 years old among each thousand of the white population—that is, about half were children. In 1900 the number of children had fallen to 356 and in New England to 291. Or, to put the matter in another form, there were in



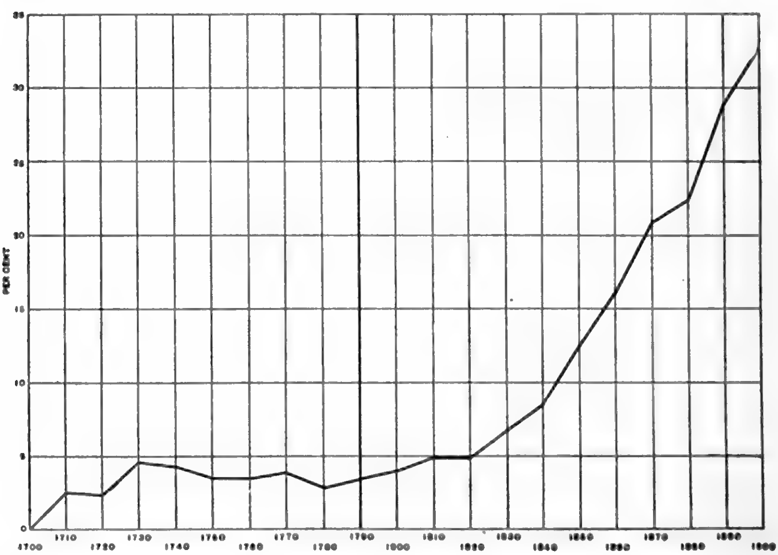
PERCENTAGE OF INCREASE IN THE POPULATION OF THE UNITED STATES BY DECADES FROM 1650 TO 1900.

1790 nearly four children under 16 for each three adults, in 1840 an equal number of children and adults, in 1900 more than three adults for each two children. If the proportion of children in 1790 had been maintained there would be at present in this country about twenty-five million children who are unborn.

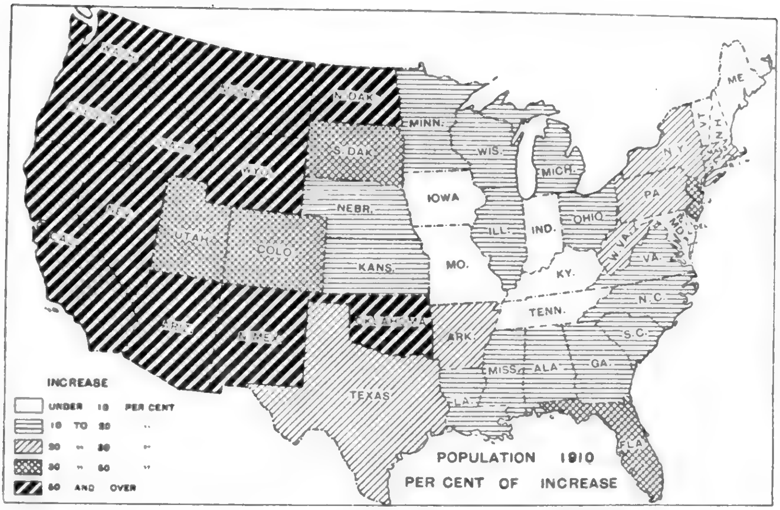
Next in significance to the declining birth rate and the lack of children and related to them is the decreasing rural population and the increasing urban population. This change is shown in the curve; the percentage of the population living in cities and towns with a population of over 8,000 has increased from 3.3 per cent. in 1890 to 32.9 per cent. in 1900. In 1790 there were six places having a population as large as 8,000; in 1900 there were 545 such places.

The increase in population of the several states from 1900 to 1910 is shown on the map. The percentage of increase is clearly greatest in the west, the population having more than doubled in Washington, Oklahoma and Idaho, and having increased more than 60 per cent. in California and Oregon. In the east Massachusetts and Pennsylvania have about maintained the average increase, while New York has exceeded it with a gain of 25.4 per cent. Although the details have not been announced it is clear that the states having relatively the largest rural population have increased most slowly. The three rural New England states show a gain of about five per cent. But the most striking fact is the stationary condition of the great agricultural states of the middle west. Iowa has actually a smaller population in 1910 than in 1900; the increase in Indiana is 7.3 per cent., in Missouri 6, in Kentucky 6.6, and these small increases are due to the cities.

The relative increase in the population of the country during the last decade was smaller than ever before and this increase was due mainly to the settling of the west and to the foreign immigration to eastern cities. The depopulation of the country districts and the lack of children are ominous for the future.



PERCENTAGE OF THE TOTAL POPULATION OF THE UNITED STATES IN CITIES OF 8,000 AND OVER.



THE RESEARCH WORK OF THE CARNEGIE INSTITUTION

Mr. Carnegie's recent gift of $10,000,000 in bonds of the U. S. Steel Corporation to the institution which he established in Washington nine years ago gives it an endowment of $22,000,000 in securities bearing 5 per cent. interest and worth at least $25,000,000. The endowment of Stanford University is about the same, and Mr. Rockefeller's endowment of the University of Chicago is about $10,000,000 greater. Each of these institutions through the gift of a single man has resources larger than any university has had until very recently, and aproximately equal to the present endowments of Harvard and Columbia. If this country does not assume the leadership in scientific research and productive scholarship, it will not be through lack of endowment.

The work of the Carnegie Institution is each year reported with clearness and fullness in the year-book. The president gives an account of the financial operations and a summary of the investigations accomplished and in progress and the heads of departments and the recipients of grants describe their work. Last year the sum of about $440,000 was appropriated for the ten research departments, about $90,000 for minor grants and research associates, about $100,000 for publications and about $45,000 for administration. Among the research departments astronomy fares the best with an appropriation of over $150,000, and geophysics and terrestrial magnetism next, with over $125,000.

The solar observatory on Mt. Wilson reports the results of nineteen researches concerned largely with sun-spots and the sun's spectrum, but extending also to stellar spectroscopy and photography. The tower telescope, shown in the accompanying illustration, is now complete except the spectroscopic attachments. A well in the rock below 75 feet deep forms part of the tube of the instrument. The meeting of the Solar Union at the observatory has been described in this journal. The department of meridian astronomy has conducted observations in Argentina and compilations at the Dudley Observatory.

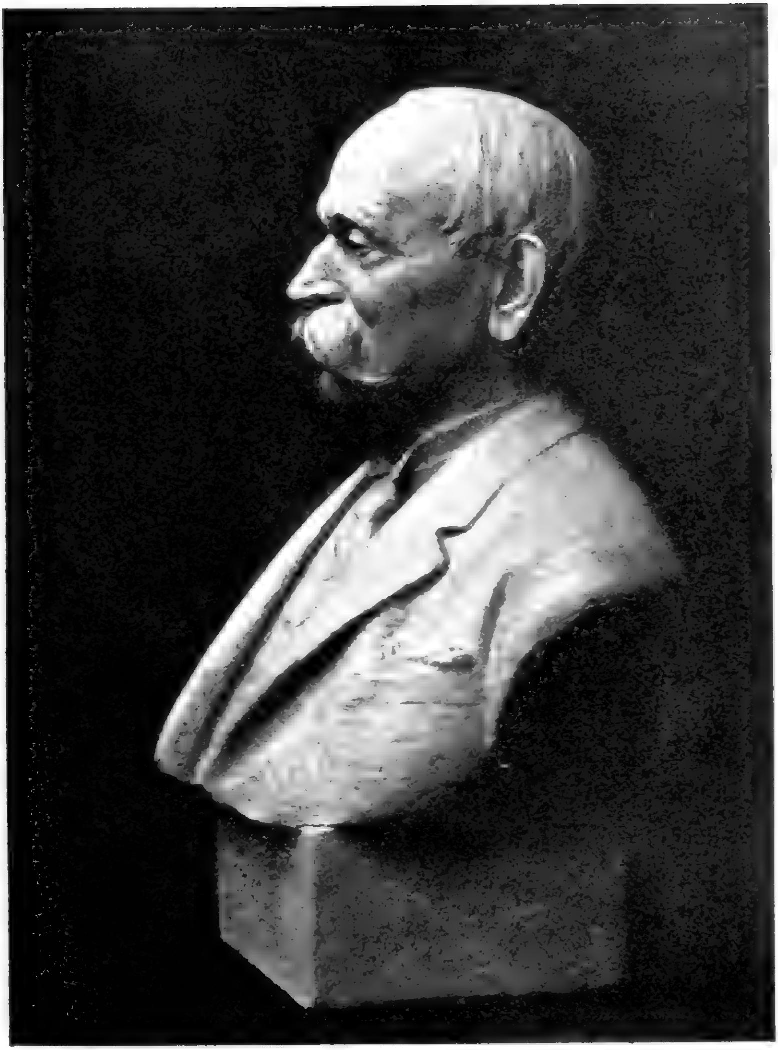
The geophysical laboratory has concerned itself with the study of rocks under experimental conditions more especially with reference to temperature and pressure. The non-magnetic ship of the department of terrestrial magnet-

TOWER TELESCOPE OF THE MOUNT WILSON OBSERVATORY.

ism, having been tested on the Atlantic, is now on a cruise around the globe which will cover about 65,000 miles.

The institution is only undertaking minor work directly in physics and chemistry, though these fundamental sciences are concerned with the research of all the departments, and in the case of the nutrition laboratory, physiological chemistry may be regarded as the field of investigation.

There are three departments devoted to the biological sciences. The work in botany has its headquarters at Tucson, Ariz., where the desert conditions are desirable for experimental research in certain directions. In equally favorable situation for its special work is the marine biological station on one of the Tortugas off the coast of Florida. The station for experimental evolution at Cold Spring Harbor, Long Island, has



Bronze Bust of Dr. C. F. Chandler.

Presented to him by the chemists of America on the occasion of his retirement from the active duties of the Mitchill chair of chemistry in Columbia University.

AN OLD CAMBRIDGE LANDMARK.

acquired additional land, including an island in the sound which can be used for the experimental isolation of plants and animals.

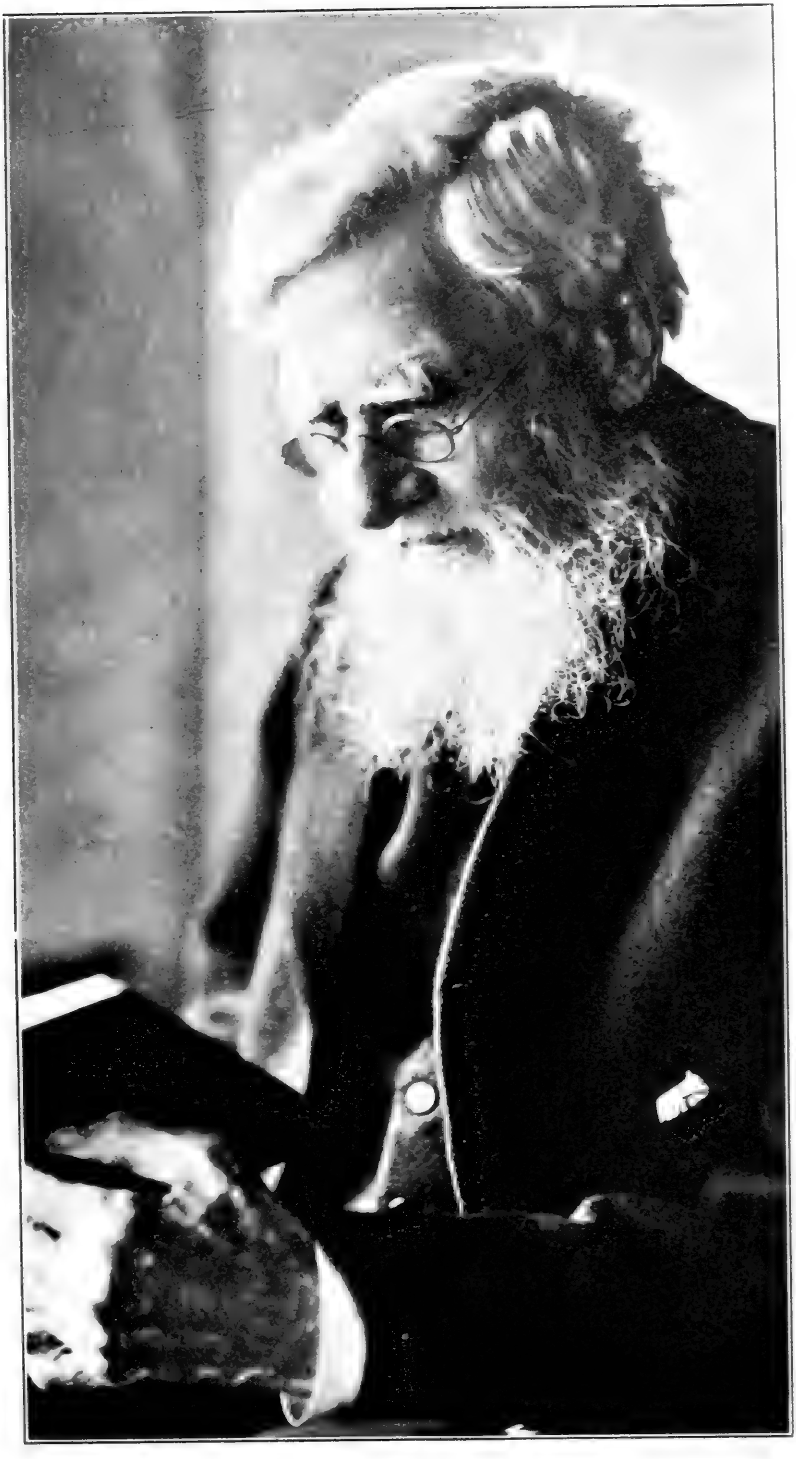
While the work of the Carnegie Institution is mainly in the natural and exact sciences there are departments of economics and sociology and of historical research, certain classes of international law are being republished and appropriations are made to the American schools of classical studies at Athens and Rome.

THE HOUSE OF ASA GRAY

The Harvard Graduate's Magazine gives a picture, here reproduced, of the house in the Botanic Garden of the university with some account of the history of this old landmark by Professor Robinson. Such a frame dwelling house is almost as characteristic of Cambridge conditions as the courts and quads of the colleges of English universities, for it has scarcely been respectable for a Harvard professor to live in a house of brick or stone. This house was built in 1810 for William Dandridge Peck, the first professor of natural history at Harvard and the organizer of the Botanic Garden. After Peck's death in 1822, it was apparently used as a boarding house and in it lived Thomas Mitchell, lecturer on natural history, an eccentric bachelor of English birth. Asa Gray was appointed professor of natural history in 1842, and lived in this house from his marriage in 1848 to his death in 1888, and Mrs. Gray continued to live there until her death in 1909. In this wooden house were kept the herbarium and library of Asa Gray until 1864, when the university provided a building, fireproof according to the standards of these days. To obtain space for the enlargement of the herbarium building and to avoid the danger from fire, the old house has now been sold and is being removed from the botanic garden, but will be restored without considerable changes in its form.

SCIENTIFIC ITEMS

WE record with regret the deaths of Dr. Edward Hitchcock, for fifty years



DR. ALFRED RUSSEL WALLACE,

the English naturalist, in his eighty-ninth year.

professor of hygiene and physical education at Amherst College; of Professor Frank J. Phillips, head of the department of forestry in the University of Nebraska; of Dr. Walter Remsen Brinckerhoff, assistant professor of pathology in the Harvard Medical School; of Dr. Aloysius Oliver Joseph Kelly, assistant professor of medicine in the University of Pennsylvania, and of Professor J. H. van 't Hoff, eminent for his contributions to physical chemistry.

THE congress has passed a bill to retire Commander Robert E. Peary, with the rank and pay of a rear-admiral and to extend to him the thanks of congress.—Sir William H. White has been awarded the John Fritz medal for 1911, for "notable achievements in naval architecture," by the national societies of civil, mining, mechanical and electrical engineering. The first award was made in 1905 to Lord Kelvin, and subsequently to Alexander Graham Bell, Thomas A. Edison, George Westinghouse, Charles Porter and Alfred Noble.—Various honors have been conferred on Dr. Paul Ehrlich, director of the Institute for Experimental Therapeutics at Frankfort, whose work was the subject of an article in the last issue of the *Monthly*. The Emperor of Russia has conferred on him the Order of St. Anne First Class, with a badge set in diamonds. The King of Spain has bestowed on him the Grand Cross of the Order of Alfonso XII. The German Emperor has nominated him a member of the senate of the recently founded Kaiser Wilhelm Society for the Advancement of Science; on this body he is the only representative of medicine. The St. Petersburg Institute of Experimental Therapeutics has elected him an honorary member. The municipal authorities of Buenos Aires have given Professor Ehrlich's name to a street in the suburb of San Fernando.

M. AUGUSTE LOUTREFIL has bequeathed $700,000 to the Paris Academy of Sciences, $500,000 to the University of Paris and $20,000 to the Pasteur Institute.—Herr Leopold Koppel, a Berlin banker, has given $175,000 for the erection of a research institute for physical chemistry in Berlin and will make a further gift of $87,500 extended over the next ten years for maintenance.—It is announced that Professor Hans Meyer has presented 150,000 Marks to the University of Leipzig for the laboratory of experimental psychology established by Professor Wilhelm Wundt.

THE POPULAR SCIENCE MONTHLY

MAY, 1911

THE FORMATION OF NORTH AMERICAN NATURAL BRIDGES

BY PROFESSOR HERDMAN F. CLELAND

WILLIAMS COLLEGE

ALTHOUGH there are more than fifty natural bridges of considerable size in North America, comparatively few persons have ever seen one, the reason being that, with the exception of the Virginia bridge and the natural bridge in North Adams, Mass., most of them are more or less inaccessible.

A bridge, according to the usual definition, is a structure that permits one to pass from one side of a depression to another, whether that depression be a railroad cut, a street or a river. As used in this article a natural bridge is *a natural stone arch that spans a valley made by running water;* a natural arch being a structure that does not span a valley of erosion.

Although a number of descriptive articles on natural bridges have

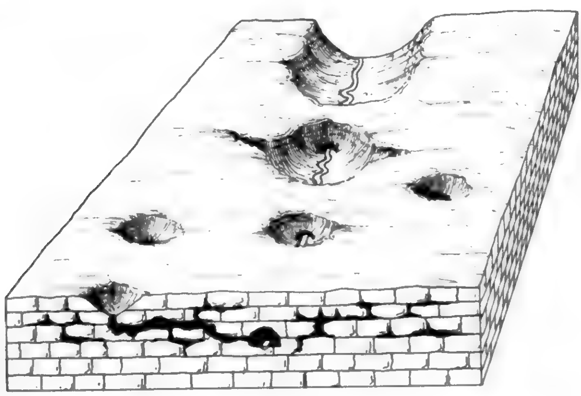


FIG. 1. BLOCK DIAGRAM ILLUSTRATING THE FORMATION OF A NATURAL BRIDGE IN LIMESTONE BY THE PARTIAL CAVING IN OF THE ROOFS OF TUNNELS.

appeared in recent years, the explanation of their origin has, for the most part, been omitted or has been unsatisfactorily given. In this paper an effort is made to show how the more important North American natural bridges were formed.[1]

In the older geologies and geographies we were taught that all natural bridges were formed in one and the same way. According to this time-honored theory natural bridges resulted from the partial caving in of the roof of an underground tunnel or cavern, the portion of the roof left spanning the chasm being a natural bridge. That natural bridges must occasionally be formed in this way is evident. For example, in Edmonson County, Kentucky, where the Mammoth Cave is situated, it is estimated that there are 100,000 miles of underground passages. In the course of time these passages will be widened and the rocks above them will be worn down by surface erosion until, at length, the roofs will almost completely disappear, leaving portions standing here and there as natural bridges. What is happening in Kentucky now has been going on for countless ages in limestone regions in other parts of the world with the possible formation (Fig. 1) and later destruction of natural bridges. It is a rather curious fact, however, that although many small natural bridges have this history, as, for example, a number of bridges in Florida, Iowa, Missouri and other states, yet, as far as known at present, none of the world's great natural bridges has this origin.

Fig. 2. The North Adams, Mass., Natural Bridge.

The Virginia natural bridge may be taken as a type of natural bridge formed by solution aided by cracks (joints). This can best be explained by a theoretical case. Let us suppose that a short distance—100 or 200 feet—above the brink of Niagara Falls the water of the river should find a crack athwart its course in the limestone bed of the river and that the water seeping through this crack should flow along the top of a lower layer, and reappear underneath the fall as a

[1] For a more complete discussion see "North American Natural Bridges, with a Discussion of their Origin," *Bulletin of the Geographical Society*, Vol. 21, pp. 313–338, July, 1910.

spring. In the course of years this underground water might eat out a channel which, in time, might accommodate a small portion of the volume of the river. This might eventually be enlarged to such an extent that all the water of the river would pass under the old bed of the river at the fall, leaving the present brink dry land; in other words forming a natural bridge under which the river would flow. The conditions above described have never been fulfilled in the case of the Niagara River and probably never will be, but they were completed in the formation of the Virginia natural bridge, and a bridge of this sort is actually in the process of formation in Two Medicine River, Montana. The height of a bridge of this origin will depend both upon the height of the original fall and upon the amount the stream deepens its valley after the formation of the bridge. The Virginia natural bridge is more than 200 feet high, but the original fall was probably less than that, since the stream has cut down its bed to some extent subsequent to the formation of the bridge.

Within the city limits of the manufacturing city of North Adams, situated in a valley which is beautiful in spite of the efforts of man to render it unsightly, is a natural bridge which well repays a visit. It is one of the most picturesque of natural bridges (Fig. 2) composed, as it is, of white marble with nearly vertical walls. It is small as natural bridges go, the top being but 44 feet above the stream bed and the cavity beneath only about 10 feet wide and 25 feet long. This bridge was formed somewhat as the one just described but differs in some important particulars.

Across the Kicking Horse River in the Canadian Rockies, a short distance from Field, B. C., amid some of the grandest scenery on the continent, within sight of primitive forests and glaciers, is a curious natural bridge and one which, at first sight, does not fulfill our conception of such a structure. In this case the opening is almost too small for the volume of the river, so that during floods the water probably flows over the top. The path which one follows in crossing the bridge is almost a horizontal S (see Fig. 3). This bridge was formed largely by "pot-hole" action. Almost everyone in New England has seen those interesting round holes which have been formed in the beds of swift streams by the whirling of pebbles in a permanent eddy until, after many years, a hole is bored which may be several feet in diameter and many feet deep. In the Kicking Horse River there was formerly a rapid or fall on which pot-holes were developed. These holes deepened and broadened at their bottoms until at length (Fig. 4) the walls of two of them were worn through near their bases and permitted the water of the river to flow through the opening thus made. In other words, the natural bridge across the Kicking Horse River is the sides of which were worn through so that the holes opened into one another.

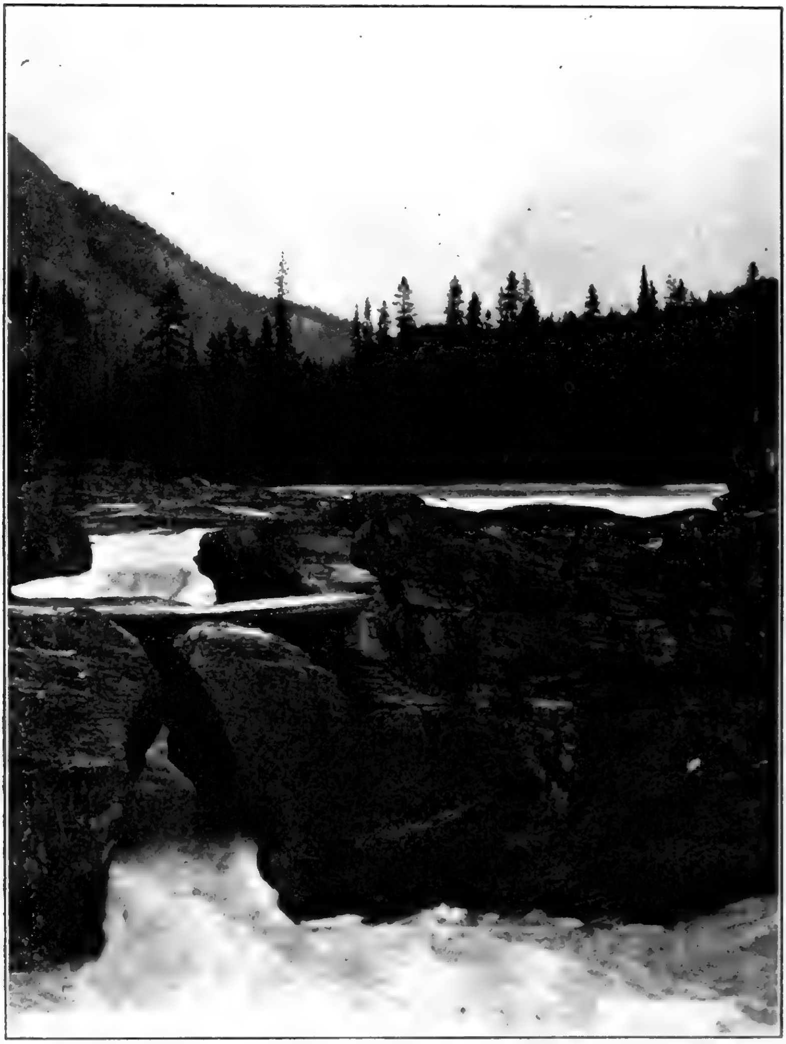


FIG. 3. THE NATURAL BRIDGE ACROSS THE KICKING HORSE RIVER NEAR FIELD, B. C. Formed by "pot-hole" action.

There are probably many small streams that are spanned by bridges of this sort, but few of them have been reported. Two such occur in Vermont.

In Kentucky are several arches with an unusual origin which should perhaps be included under the term natural bridge. They were formed in a plateau composed of horizontal sandstone and limestone by the cutting back of the heads of two streams flowing in opposite directions in deep valleys. The streams continued to cut back until only a narrow ridge or divide separated their basins. This divide was in time perforated by the action of water, wind and frost until at length a fine bridge resulted. One of these (Fig. 5) near the station of Natural Bridge on the Lexington and Eastern Railroad, is 32 feet high and 66 feet wide. There are three bridges, or arches, of this origin within a radius of three or four miles.

In narrow mountain valleys natural bridges are sometimes formed by a large rock falling down the mountainside and wedging into the valley. In Switzerland two bridges of this sort are actually in use by pedestrians, but none has been reported in this country, though many doubtless exist. An unusual bridge formed by gravity (Fig. 6) is one consisting of a large slab which was separated from one side of a valley and fell to the other side. When the crack was filled with débris a usable bridge resulted.

In the Yellowstone National Park a natural bridge (Fig. 7) composed of a lava made up of vertical plates of compact and porous rock spans Bridge Creek near Yellowstone Lake. The bridge, although only forty feet high, is very interesting, both because of its rugged beauty and of its unique origin. An examination shows that the bridge is made of two vertical slabs of lava, one two feet and the other four feet thick, separated by an opening two feet wide. The bridge was formed as fol-

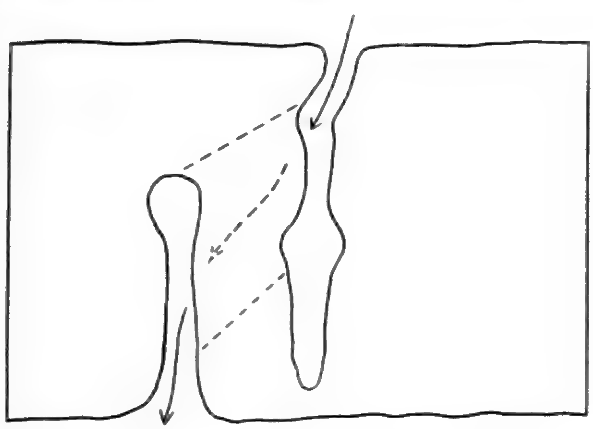


FIG. 4. DIAGRAM SHOWING THE COURSE OF THE KICKING HORSE RIVER UNDER THE BRIDGE. (See Fig. 3.)

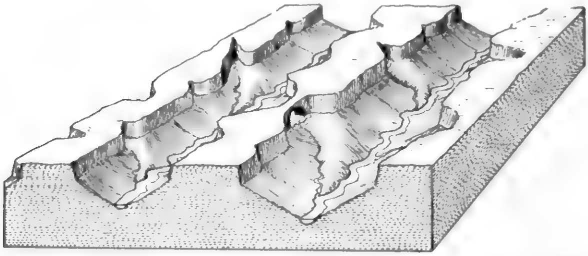


FIG. 5. A NATURAL BRIDGE NEAR THE STATION, NATURAL BRIDGE, KENTUCKY.

lows: at one time the stream flowed over a fall which is now represented by the top of the bridge: in the course of time the freezing of the water between the thin vertical plates of which the slabs are composed at the foot of the fall forced them apart, making it easy for the water from the fall to wear away the rock at its foot and to excavate a cave. This cavity was gradually extended up stream until a porous layer was encountered through which the water of the stream poured into the cavity, thus forming a bridge of the first of the two slabs. The same process was continued with the undercutting of the second slab. In this way a natural bridge was formed. It is hardly probable that another structure made in the same way is in existence.

It does not seem possible at first thought that a natural bridge more than 125 feet high could be formed by the deposit of lime from water (travertine), but such a bridge (Fig. 8) occurs near the little Mormon

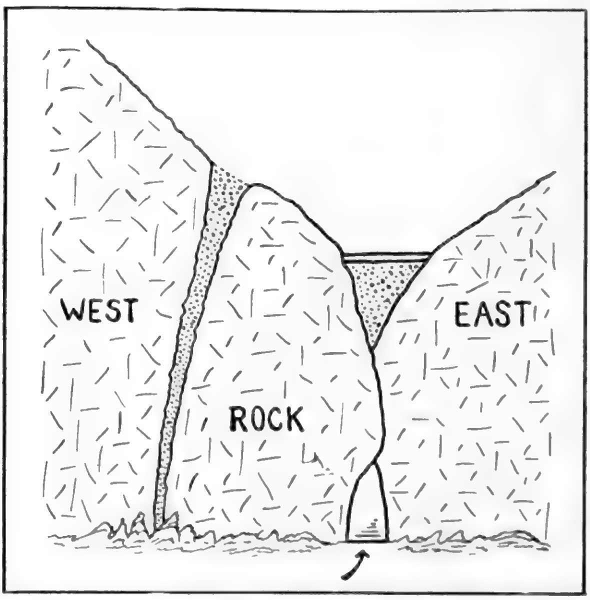


FIG. 6. BLOCK DIAGRAM TO SHOW A BRIDGE FORMED BY THE HEADWARD CUTTING OF TWO STREAMS IN A PLATEAU REGION.

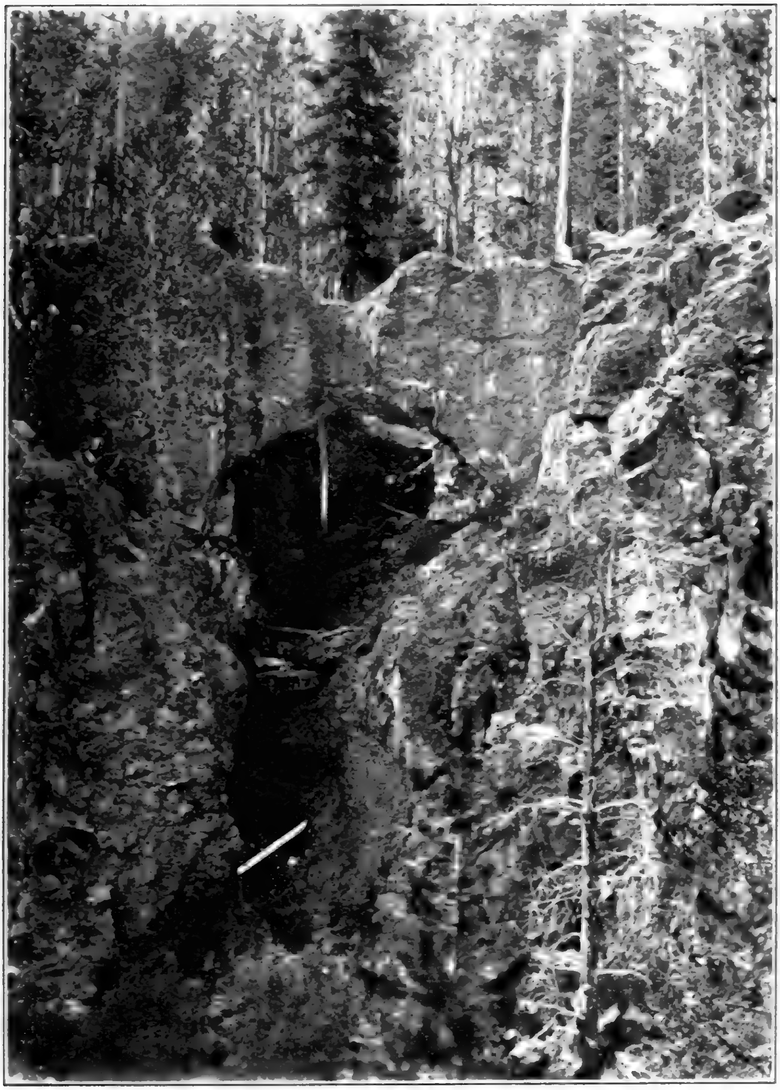


FIG. 7. THE LAVA NATURAL BRIDGE ACROSS BRIDGE CREEK, YELLOWSTONE NATIONAL PARK.
Simply that portion of the rock of the former fall between two pot-holes.

village of Pine about 90 miles south of Flagstaff in Arizona, and can be reached by a horseback journey of three days from that city. As one travels south from Flagstaff through the forest reservation he passes for miles over a lava plateau which, were it not for the pines and cedars, would be called a desert. The forest does not fulfill the usual conception of a wooded region since the trees, though gigantic, are far apart and underbrush is entirely absent. After many hours of travel over a

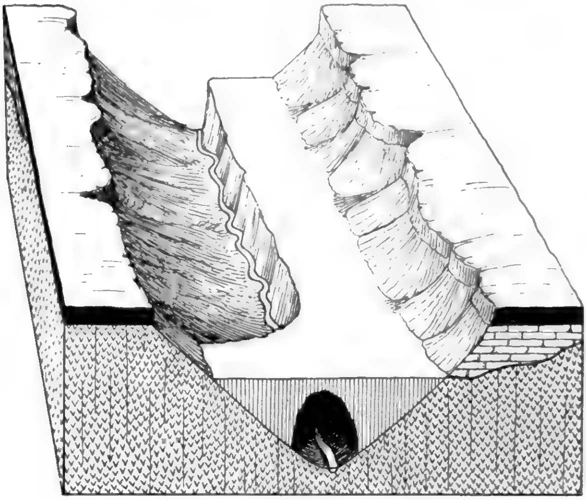


FIG. 8. BLOCK DIAGRAM TO SHOW THE FORMATION OF THE TRAVERTINE NATURAL BRIDGE AT PINE, ARIZONA. This bridge was formed by the deposits of travertine derived from the springs on the east. (In the diagram the height of the bridge is exaggerated.)

country of this sort, the brilliant green of the irrigated valley of which the natural bridge is a part seems remarkably beautiful and is a sight not soon forgotten. Not only is the bridge composed of this limestone

FIG. 9. TWO VIEWS OF THE NATURAL BRIDGE ACROSS SWIFT'S CAMP CREEK, NEAR CAMPTON, KENTUCKY. (See Fig. 10.)

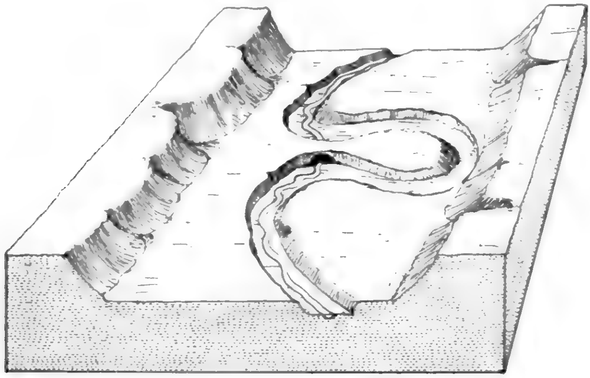


FIG. 10. BLOCK DIAGRAM TO SHOW THE FORMATION OF A NATURAL BRIDGE BY THE PERFORATION OF AN ENTRENCHED MEANDER. (See Fig. 9.)

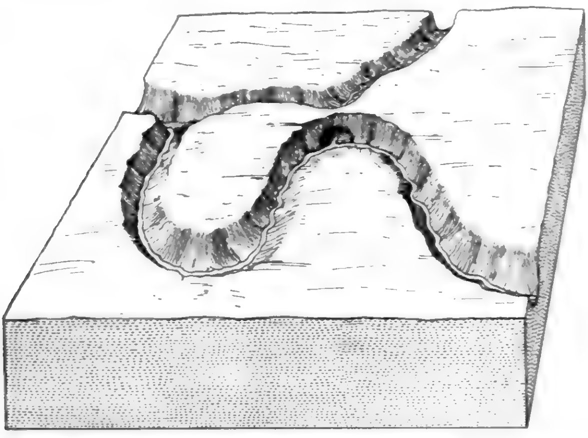


FIG. 11. BLOCK DIAGRAM TO SHOW A BRIDGE FORMED BY THE TUNNELING AT A MEANDER BEND OF A NARROW DIVIDE BETWEEN THE MAIN AND TRIBUTARY STREAM.

deposit (travertine) but also the whole of the cultivated valley of about 25 acres. The bridge has a span of 140 feet, a height of more than 125 feet and a width of about 400 feet. In fact the bridge is so large that the visitor is likely to walk over it, as the writer did, without knowing he is on it. The top of the bridge is under irrigation and produces crops of alfalfa.

The formation of the bridge is simple and the process can sometimes be seen when moist, drifting snow forms a bridge across a small valley. Several large springs that empty into the valley on the east contain lime in solution which, upon evaporation or loss of carbonic acid gas, is deposited. For many years this deposit has been accumulating and with sufficient rapidity to force the stream (Pine Creek) to the west side of the valley. In one place the deposition was rapid enough and the travertine strong enough to arch over the creek and buttress itself on the opposite bank, thus forming a natural bridge. The deposition does not seem to be going on as actively now as formerly, but in one place the lime is being deposited so rapidly that hats, shoes and other objects left in the spray are coated over with a thick layer of lime in a few months. Underneath the bridge are caves of considerable size adorned with stalactites and stalagmites.

The greatest natural bridges of the United States, and of the world, are found in southeastern Utah. These were formed in a manner so simple that the explanation may, at first, seem inadequate. The streams which they now span have great bends and formerly had greater ones. As they deepened their beds they kept cutting away on the inside of these curves. In some cases the streams probably cut through the necks of these meanders without the formation of bridges, but in four instances the stream perforated the neck of the bend, forming natural bridges. These Utah natural bridges are enormous, varying in height from 108 to 308 feet, and in length of span from 186 to 275 feet. The bridges are made of red sandstone and occur in a high plateau in which the streams have cut canyons hundreds of feet deep.

An interesting bridge of a similar origin spans Swifts Camp Creek (Figs. 9 and 10) in the mountains of eastern Kentucky. Although the top of the bridge is but 15 or 20 feet above the surface of the stream and the length of the span is only 50 feet, yet it illustrates as well as the great Utah natural bridges the manner in which the stream has worked to accomplish this result. The greatest natural bridge in Europe, the Pont D'Arc across the Ardêche has a similar origin, as can readily

FIG. 12. A NATURAL BRIDGE BELOW CREELSBORO, RUSSEL COUNTY, KENTUCKY, formed as shown in Fig. 11.

FIG. 13. A NATURAL ARCH NEAR SANTA CRUZ, CALIFORNIA, FORMED BY WAVE ACTION.

be seen by a study of a map of the region. Another Kentucky bridge formed by the lateral erosion of a tributary stream has produced a perforation (Figs. 11 and 12). The water flows through the opening into the tributary stream when the river is high and from the tributary to the river when the water in that is high. One at least of the Utah bridges may have been formed in this way.

On the coast of California is a natural arch (Fig. 13) made by the beating of the waves against a cliff of soft shale. The top of the arch is so level that a team of horses can be driven across it in safety. It was formed by the partial falling in of the roof of a sea cave. Openings of a similar nature are not uncommon on rough and stormy coasts but it is seldom that a structure so perfect as this is formed.

It will be seen from the above that natural bridges are formed in many ways: that they are not confined to any particular kind of rock, nor are they restricted to any particular region but are found alike in deserts and fertile lands, in mountains and on plateaus.

Natural bridges are short lived, geologically considered. The marble natural bridge in North Adams, Mass., for example, was formed many years after glacial times, but already a portion of the bridge has fallen in. Since the great ice sheet is believed to have disappeared from Massachusetts between 20,000 and 80,000 years ago and since this bridge was not formed until long after it had vanished, it will be seen that the life is not long as time goes. Nevertheless, short lived as they are geologically, some of them probably were in existence when the human race was very young.

SOME WEATHER PROVERBS AND THEIR JUSTIFICATION

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"So it falls that all men are
With fine weather happier far."
—*King Alfred.*

THIS thousand-year-old observation by England's wisest ruler recognizes the fact that fine weather induces good tempers, and therefore amply justifies the proverb that shrewdly bids one "Do business with men when the wind is in the northwest."

But this effect on the minds of men does not exhaust the good and the evil of weather conditions, since our comfort, our convenience and even the success or failure of whatever we undertake, all depend, in large measure, upon clear skies and cloudy, upon wind and rain, and upon everything that renders the elements fair or foul.

Because, then, of the great influence weather conditions have over human affairs numerous rules for foretelling their coming changes have been formulated in all ages and by all peoples. While many of these rules are of general application, many others, as might be suspected, have only a local value, and owe their justification to some peculiar configuration of mountain and valley, or distribution of land and water, and, therefore, when transferred to other places commonly are meaningless, if not even misleading. Nevertheless, all of them, the wise and the silly, the good and the bad, have been inherited alike from the ends of the earth; and in this way many a concise saying has become a weather nugget in that great vein of wisdom and folly called folk lore.

Some of these nuggets are as pure gold, for they correctly state the actual order of sequence, as determined by innumerable observations, even when the cause for such an order was not in the least understood by those who discovered it; but most of them are as only fools' gold, pretty in form, but wholly deceptive. To this latter class belong hundreds of proverbs of the ground-hog and goose-bone type; some owing their origin to one thing and some to another, but, like predictions based upon the weather of saints' days, or upon the phase of the moon and the pointing of its horns, never for a moment accepted by those whose reason demands an adequate cause for every effect.

But that other class of weather proverbs, those that do have more or less to support them, is worthy of very careful consideration and study, for they embody accurate descriptions of phenomena and express the usual sequence of events.

It can be argued, of course, and apparently with good reason, that, in spite of its scientific interest, such a study can not now have any practical use, since nearly every country has a national weather service whose forecasts, for any given time and place, are reliably based upon the known immediately previous conditions all over a continent—conditions that are followed from hour to hour and day to day; that are minutely recorded and carefully studied.

It is true that when one is supplied with such information his horizon becomes world wide; that he sees the weather as it is everywhere; knows in what directions the storms are moving and how fast, and that, therefore, he can predict the approximate weather conditions for a day or more ahead. But in general it is not practicable officially to forecast for definite hours, nor for particular farms and villages. In the making, then, of hour-to-hour and village-to-village forecasts, though often of great value, one must rely upon his own interpretation of the signs before him. Besides, in many places it is impossible to get, in time for use, either the official forecast or the weather map upon which to base one's own opinions, and under these conditions certain weather signs are of especial value—signs which every one uses to a greater or less extent, but with an understanding of their significance that, according to such experience as only real necessity can give, varies from the well nigh full and complete to the vague and evanescent.

Thus the fisherman to-day, as in the past, will weigh anchor and flee from the gathering storm when to the uninitiated there is no indication of anything other than continued fair weather; and the woodsman, as did his remotest ancestors, will note significant changes and understand their warning messages when the average man would see no change at all, or, if he did, would fail to comprehend its meaning.

The prescience of these men is phenomenal, and it is with some of the useful weather proverbs they know so well, the causes of the phenomena they describe and the relation of these phenomena to others they precede, that the following is concerned.

Seasons

"A good year is always welcome."

Naturally every one asks: "What of the coming season?" And especially is this an important question for the farmer, for a correct answer to it would tell him what crops to plant and where; whether upon hill or lowland, in light or heavy soil, and how best to cultvate them—vital points, every one, for his success. But whatever we may hope ultimately to accomplish, seasonal forecasting to-day is beyond the pale of scientific meteorology, though proverb meteorology is full of it. However, a few of the seasonal proverbs that deal with results rather than types of weather are rationally founded.

Among them we have:

"Frost year,
Fruit year."

"Year of snow,
Fruit will grow."

Or, in still another form:

"A year of snow, a year of plenty."

That these and similar statements commonly are true is evident from the fact that a more or less continuous covering of snow, incident to a cold winter, not only delays the blossoming of fruit trees till after the probable season of killing frosts, but also prevents that alternate thawing and freezing, so ruinous to wheat and other winter grains. In short, as another proverb puts it,

"A late spring never deceives."

A different class of proverbs, but one meaning practically the same thing as the foregoing, and justified by substantially the same fact, that is, that an unseasonably early growth of vegetation is likely to be injured by later freezes, is illustrated by the following examples:

"January warm, the Lord have mercy!"

"If you see grass in January,
Lock your grain in your granary."

"January blossoms fill no man's cellar."

"January wet, no wine you get."

"January and February,
Do fill or empty the granary."

"All the months in the year
Curse a fair Februeer."

There are hundreds of other proverbs dealing with seasonal forecasts, but, except those belonging to such classes as the above, they have very little to justify them. Many are purely fanciful and others utterly inane.

Sun

"Above the rest, the sun who never lies,
Foretells the change of weather in the skies."
—*Virgil.*

While proverbs concerning the seasons, in the most part, are built upon the shifting sands of fancy and of superstition, many, but not all, of those that concern the immediate future—the next few hours, or, at most, the coming day or two—are built upon the sure foundation of accurate observation and correct reasoning. Among these perhaps the best are those that have to do with the color of the sky and the appearances of the sun, the moon and the stars, for we see the first because of our atmosphere, and the others through it and, therefore, any change in their appearances necessarily means changes in the atmosphere itself—changes that usually precede one or another type of weather.

A familiar proverb of this class runs as follows:

"A red sun has water in his eye."

Now the condition that most favors a red sun is a great quantity of dust—smoke particles are particularly good—in a damp atmosphere. Smoke alone, in sufficient quantity, will produce this effect, but it is intensified by the presence of moisture. The blue and other short wavelength colors, as we call them, of sun light are both scattered and absorbed to a greater extent by a given amount of dust or other substances, such as water vapor, than is the red; and this effect, since it is proportional to the square of the volume, becomes more pronounced as the particles coalesce. Hence when the atmosphere is heavily charged with dust particles that have become moisture laden, as they will in a humid atmosphere, and therefore relatively bulky, we see the sun as a fiery red ball. We know, too, that this dust has much to do with rainfall for, as was first proved many years ago by the physicist Aitken, cloud particles, and, therefore, rain, will not, under ordinary conditions, form in a perfectly dust-free atmosphere, but will readily form about dust motes of any kind in an atmosphere that is sufficiently damp.

A red sun, therefore, commonly indicates the presence of both of the essential rain elements, that is, dust and moisture; and while the above is not the whole story, either of the meteorological effects due to dust in the air, or of the formation of rain, it is sufficient to show how well founded the proverb under consideration really is. And also this other one that says:

"If red the sun begin his race,
Be sure the rain will fall apace."

Sky Colors

"Men judge by the complexion of the sky
The state and inclination of the day."
—*Shakespeare.*

There are many proverbs, ranging from the good and useful to the misleading and absurd, concerning the color of the sky at sunrise and sunset.

From Shakespeare we have the well-known lines:

"A red morn that ever yet betokened
Wreck to the seaman, tempest to the field,
Sorrow to the shepherds, woe unto the birds,
Gusts and foul flaws to herdsmen and to herds."

Besides these stately verses there are many proverb jingles that express substantially the same idea. One of them puts it thus:

"Sky red in the morning
Is a sailor's sure warning;

Sky red at night
Is the sailor's delight."

But in many ways the most interesting of all those proverbs that have to do with red sunrise and red sunset is the one which, according to Matthew, Christ used in answer to the Pharisees and Sadducees when they asked that He would show them a sign from heaven.

"He answered and said unto them, When it is evening, ye say, It will be fair weather: for the sky is red.

"And in the morning, It will be foul weather to-day: for the sky is red and lowring."

It would seem, too, that Christ sanctioned these views, for it does not appear reasonable that He would teach by illustrations which He knew to be false. Then, too, He follows the above with these words:

"O ye hypocrites, ye can discern the face of the sky; but can ye not discern the signs of the times?"

But whether or not Christ accepted these weather signs as being good, we feel certain that those to whom he spoke must have known and believed in them. It is, therefore, worth while to search, even though the search be a somewhat tedious one, for the physical explanation of these phenomena, and to see how it is possible, if it really is, for identically the same colors of the sky to have for the evening one meaning, and for the morning another entirely different.

To clear the way for this explanation it is necessary, first, to tell something of the composition of sunlight, and a little about the atmosphere through which it passes on its way to the surface of the earth.

We know that rain drops are colorless, and we know, too, that when we are between a falling shower and the bright sun they give us the exquisite coloring of the rainbow. We are also aware that prism-shaped, colorless and transparent objects will receive a ray of white sunlight and emit all the rainbow's brilliant hues, from the faintest violet to the deepest ruby: and that when these are recombined the result is white light like the original. Through such experiments and observations we infer that sunlight is composed, in part at least, of all pure colors, and that they gradually merge the one into the other.

Again, it is possible to obtain two sources of light of the same color and intensity such that at certain places they produce more than twice—in fact up to fourfold—the intensity of one alone, and at certain other places intensities less than that of just one, even to utter darkness. Now this tells us that in some respects two lights behave in a manner similar to two trains of water waves, for these may combine so as at some places to produce exceptionally large waves and at others practically smooth water. Indeed, it has been shown by numerous experiments that light has several properties in common with water waves; one of these being wave-length, that is, the distance from a point in one wave to the corresponding point of its nearest neighbor, as, for instance, from crest to crest.

Of all colors violet light has the shortest wave-length, and red the longest. Blue is next to violet, yellow next to red, and green about an average of all. The wave-length of red light is less than twice that of the violet, and yet it would take more than 30,000 of the longest waves to which the eye is sensitive to span a single inch.

Turning, now, our attention to the atmosphere, we find that at nearly all times, and everywhere within two miles of the surface, and probably much higher still, it contains, in every cubic inch, thousands of dust particles coming from fires, from plants, from the dry earth as caught up by winds, and from still other sources. Much of this dust is excessively fine and settles down with extreme slowness. It serves, as already explained, as nuclei about which the myriads of cloud droplets are formed.

In addition to this important function, extremely fine particles of dust, and even single molecules, but not the coarser portions, as shown many years ago by Lord Rayleigh, both scatter and absorb light of all colors according to the laws: (1) that the amount both of absorption and of scattering decreases in the same proportion that the fourth power of the wave-length increases; (2) that both increase with the number of particles per unit volume, and with the average square of the volume of the individual particle.

The refractive index of the air and of the foreign substances it contains, together with certain numerical terms, also enter into the complicated equations that deal quantitatively with atmospheric absorption and scattering of light. These latter facts, since they are not essential to what follows, are mentioned here only for the sake of completeness.

Now scattering and absorption, acting according to the above laws, combine to give us the colors of the sky, because sky light is only the residual, after absorption, of that portion of sunlight which was scattered by the molecules of the atmosphere and by the foreign substances floating in it.

Since, according to the first law, but little light of very long wave-length is scattered while nearly all of exceedingly short wave-length is absorbed, it follows that the light of maximum intensity, or the prevailing color, must have some intermediate wave-length. Hence the sky overhead is neither red (long wave-length) nor violet (short wave-length). Also, from the second law, we see that different parts of the sky at the same time, and the same parts of the sky at different times, will have different colors owing to the amount, aggregation and distribution of atmospheric dust.

When these particles are relatively few and small the prevailing color is blue. On the other hand, where the dust motes increase in size and number, as they do near the surface of the earth, or in size only, even at the expense of numbers, as happens in a moist atmosphere, because of their hygroscopic property, light of the shorter wave-lengths becomes more completely absorbed and the sky assumes some longer wave-length color. Finally, when the particles are large enough to reflect as mirrors the sky becomes whitish. Hence both the morning and the evening twilight sky often shows a series of colors ranging from red, near the horizon, through orange and yellow to a green or even blue-green with increase of elevation and consequent decrease in the number and size of dust particles along the path of light from the sun to that part of the sky in question and thence to the observer.

When the air is filled with fog, or other particles of similar size, the whole sky becomes uniformly gray. This is because the water droplets that together make fog and cloud, though usually so small that it would take from 2,000 to 3,000 of them to make a row an inch long, nevertheless are large enough to reflect, as would little mirrors, and to refract, or transmit in a new direction, light of every color.

It remains now, in preparing the way to an understanding of the weather significance of morning and evening colors, briefly to outline the essential conditions and processes of cloud formation and rain.

Probably that one of these conditions with which the general public is least familiar is the presence, in large numbers, of some sort of nuclei about which water vapor can condense. We can safely assume, too, that in the open atmosphere these nuclei consist only of dust particles, though it is possible in the laboratory, under conditions that rarely, if ever, exist naturally, to obtain condensation without the aid of dust of any kind.

Besides the presence of dust particles, a certain relation between temperature and water content of the atmosphere is also essential to condensation. The warmer the air, so long as the temperature is below the boiling point, the greater, and, for ordinary temperatures, at a rapidly increasing rate, the amount of water vapor it can contain in the form of a transparent gas.

In reality the relation above discussed is between the temperature and amount of moisture per unit volume, a quantity which does not appreciably change with the presence or absence of other gases. But it is allowable, because of this constancy, to use the popular, though unscientific, expression, "water content of the atmosphere," provided one thinks of the atmosphere as a mixture of gases (chiefly nitrogen and oxygen) coexisting with the undisturbed water vapor, and not as a sort of sponge that mechanically holds it in suspension.

If, then, air, which always has dust particles in it, containing all or nearly all the water vapor it can hold, is cooled to a distinctly lower temperature, a corresponding amount of condensation will take place on each dust mote, and the countless droplets thus formed will appear as a fog or cloud of greater or less density.

The most efficient method of producing the cooling necessary to cloud formation is to move the moist air to a place of lower pressure, that is, lift it to a greater elevation, where it will expand and thereby do work against the surrounding decreased pressure at the expense of the heat energy it contains. This effect is well illustrated by the formation of cumuli, or thunderhead clouds, in the summer time; the process of which, in general, is as follows: The earth is heated by sunshine and it in turn heats and expands the adjacent atmosphere and thereby renders it lighter, volume for volume, than the surrounding cooler air. The light, warm atmosphere often nearly saturated with water evaporated from lakes, from moist earth and growing vegetation, and by this vapor rendered still lighter, is buoyed up by cooler and heavier adjacent air, very much as a cork is made to bob up when let go beneath a water surface. The lifted, or, as we commonly say, the rising air, sustains at any particular time only the weight of the atmosphere that is at that moment above it. But, clearly, so long as the air is rising this weight is growing less, and therefore as it passes from a region of greater to one of less pressure it expands just as a compressed spring does when its load is decreased. However, as the spring expands it must do the work of lifting the remaining weight, and so it is with the atmosphere; in expanding it has to lift the air that is above it and thereby do work. Now this work is possible only because of the heat of the active air itself, and consequently as it expands it correspondingly gets cooler. But, as has already been explained, the amount of water vapor that any given volume can hold in the form of a transparent gas, rapidly decreases as the temperature falls.

A rising mass of air, therefore, cools by virtue of its own work in expanding against pressure, and soon reaches a temperature below which it can not contain, as a gas, all its water-vapor. Hence any further rise and consequent cooling leads to precipitation—a collection of the excess water vapor in droplets about dust particles—and the formation of clouds.

With the foregoing facts in mind it is easy to understand, in a general way, those actions of nature that give meaning to the sky colors of morning and evening, and, in large measure justify the proverbs that for ages have been associated with them. Thus we see that a red evening sky means that nothing more than incipient condensation exists even at the tops of the strongly cooled convection currents that obtained during the heated portion of the afternoon (more than this would produce a gray or even cloudy sky), and that therefore the air contains so little moisture that rain, within the coming twenty-four hours, is improbable.

If the evening sky, not far up, but near the western horizon, is yellow, greenish, or some other short wave-length color, then all the greater is the chance for clear weather, for these colors indicate even less condensation (smaller particles) and therefore a dryer air than does red. Hence we can accept the following lines from Shakespeare as the expression of a general truth:

> "The weary sun hath made a golden set,
> And by the bright track of his fiery car
> Gives token of a goodly day to-morrow."

If, however, the evening sky has none of these colors, but is overcast with a uniform gray, then we know that numerous water droplets are present, and that the dust particles, in spite of the heat they absorbed from sunshine, have become loaded with much moisture. Obviously, then, to produce this effect, the atmosphere, at considerable elevations, must be practically saturated, a condition that favors rain and justifies the familiar proverbs:

> "If the sun set in gray
> The next will be a rainy day."

> "If the sun goes pale to bed
> 'Twill rain to-morrow, it is said."

The above discussion of color phenomena applies to the evening sky only. It remains to explain the origin of similar morning effects and to point out the differences in the processes by which they are brought about.

A gray morning sky means, just as does a gray evening one, that the atmosphere is filled with water globules which are large enough, and even the smallest of them are, to refract and specularly reflect light of every color. The difference, then, must be in the processes that lead to the formation of the evening and the morning droplets. And these processes are not the same, for the dust of the day sky is heated by sunshine, as are also, to a greater or less extent, both the air and the earth beneath, while the dust in the night sky, as does everything else that is freely exposed, loses of the heat it possesses and cools through radiation to space. Besides, the atmosphere during the day time, and especially in the afternoon, is cooled by convection, which, as already explained, leads to more or less condensation of moisture on the dust that is present; while at night there is no strong upward movement, there being no surface heating, and consequently but little dynamic cooling of the air. The slight condensation here considered is due by day chiefly to convectional cooling, by night mainly to loss of heat through radiation.

Evidently, then, the gray of the morning sky may often be caused by water droplets that have gathered as so much dew on the dust particles in the air—dew that has collected on them because of the slightly lower temperature they maintain through radiation to space, just as, and for the same reason that it collects on blades of grass and other exposed good radiators. But in order that the marked radiation, essential to the formation of the water droplets, may take place, it is necessary that the atmosphere above them be dry, for water vapor does not allow radiation freely to pass through it. Hence a gray morning sky implies a dry atmosphere above the dew droplets, and, therefore, justifies the expectation of a fair day, or even a clear one, for the droplets themselves to which the gray is due are soon evaporated by the rising sun, and convection, in this case, because it mixes the moist lower with a dry upper air, seldom causes precipitation.

A red morning sky commonly implies that the lower and heavier dust particles have been protected from excessive night radiation by a blanket of overlying moisture, else it would be gray; and at the same time it also implies the presence, in the lower atmosphere, of sufficient moisture to enlarge the dust particles through incipient condensation, else the sky would have some shorter wave-length color, such as yellow to green. Hence when the morning sky is red the whole atmosphere, to considerable elevations, is moist, and rain, therefore, probable.

Convection in the main, as we have seen, prepares the way for the phenomena of the evening sky, and radiation for those of the morning sky. Hence the amount and distribution of moisture most favorable to any given sky color, such as a gray or a red, are radically different in the two cases. There is, therefore, a real physical basis for, and much truth in, the proverbs that declare one result to follow the red of morning and quite another that of evening. There is also justification for some proverbs, two of which have already been given, that refer to or include other colors.

Additional good examples of the latter are as follows:

"Evening gray and morning red
Make the shepherd hang his head."

"An evening gray and a morning red
Will send the shepherd wet to bed."

"Evening red and morning gray
Two sure signs of one fine day."

"Evening red and morning gray
Help the traveler on his way;
Evening gray and morning red
Bring down rain upon his head."

Coronas and Haloes

"For I fear a hurricane;
Last night the moon had a golden ring,
And to-night no moon we see."

—*Longfellow.*

Many proverbs foretelling rain and bad weather are based on the appearance of solar and lunar haloes and coronas, and as these form only when there is much moisture in the air and some condensation the proverbs of this class are well founded.

Coronas are the small colored rings of light that encircle any bright object when seen through a mist, though the term commonly is used to designate only the colored rings around the sun and moon. They are due to diffraction (the bending of light at the boundary of an object into its geometric shadow) caused by water globules, and have one or another angular diameter depending on the size of the droplets that produce them, in the sense that the larger the droplets the smaller the corona. Hence a decreasing corona implies growing drops and the probability of an early rain.

Haloes, on the other hand, are the rings of large diameter, usually colorless or nearly so, due to reflection and refraction by ice spicules, and are often seen in the high cirrus clouds that have been caught up from the tops of storms and carried forward by the swiftly moving air currents that always prevail at such elevations. It is this usual position of haloes relative to storm centers, that is, in front of them, that makes them the good indicators they are of approaching bad weather.

Typical of such proverbs is that of the Zuñi Indians, who say:

> "When the sun is in his house it will rain soon."

Several others refer to the apparent diameter of the circle. Thus we have:

> "Far burr, near rain."
>
> "The bigger the ring, the nearer the wet."
>
> "When the wheel is far the storm is n'ar;
> When the wheel is n'ar the storm is far."

These latter can not refer to the corona, which actually does change in angular size, because in that case just the reverse is true; the bigger the ring the farther off the storm. Clearly then they apply only to the halo, and as the apparent size of an object of constant angular diameter depends upon its seeming distance away, it follows that the supposed changes referred to are optical illusions, due to erroneous impressions of distance.

A good illustration of this kind of illusion is furnished by the moon as seen by different people, or as seen by the same person at different elevations above the horizon. When high in the heavens, where it appears to be comparatively near, it looks smaller than it does when close to the horizon where it seems to be farther away; and yet careful measurements show but little change in its angular diameter, and that little just the reverse of appearances.

Hence, when the actual distance to a halo is less than it seems to be, as often happens when the clouds are low, it appears to be unusually large; and, conversely, when the clouds are very high a halo in them, because the distance to it commonly is underestimated, impresses one as being correspondingly small.

Now the higher the clouds the swifter the winds that carry them along and the farther removed they become from the storm center. Hence, a halo that appears small is due to clouds far removed from the storm that produced them, while one that seems large, since it is caused by relatively low and, therefore, slow-moving clouds usually indicates that the storm is comparatively near.

Moon

"But chiefly look to Cynthia's varying face;
There surest signs of coming weather trace."
—*Aratus.*

Many people have supposed, and some still hold, that the moon appreciably controls the weather, and there are numerous proverbs based on this assumed relation. But careful study of the records shows that the moon's influence on the weather, beyond a very small tidal effect on the atmosphere, as indicated by the barometer, is negligible, if indeed it has any influence at all. As has been well said:

"The moon and the weather
May change together;
But change of the moon
Does not change the weather.
If we'd no moon at all,
And that may seem strange,
We still should have weather
That's subject to change."

However, the appearance of the moon depends upon the conditions of the atmosphere, and, therefore, proverbs based upon phenomena of this nature are more or less sound and have much value. Thus:

"Clear moon
Frost soon,"

"Moonlit nights have the heaviest frosts,"

and others of this class are true enough, because on the clearest nights the cooling of the earth's surface by radiation is greatest and hence most likely to cause, through the low temperature reached, precipitation in the form of dew or frost.

The meaning of haloes and coronas about the moon has already been explained, and the proverbs connected with them, foretelling bad weather, fully justified.

The following is a somewhat interesting moon proverb:

"Sharp horns do threaten windy weather."

When the air is clear bad seeing is due to atmospheric inequalities which the free mixing caused by winds will eliminate. When the moon's horns, then, appear sharp, that is, when the seeing is good, we know that these inequalities do not exist, and the natural inference is that they have been smoothed out by strong overrunning winds, which later may reach the surface of the earth.

Stars

> "The prudent mariner oft marks afar
> The coming of tempests by Boötes's star."
> —*Aratus.*

The stars, like the sun and the moon, have furnished a number of proverbs concerning the weather, and, while most of them are only nonsense, a few have decided merit, as, for instance:

> "When the stars begin to huddle,
> The earth will soon become a puddle."

This proverb furnishes, in general, a correct forecast. It also affords a curious illustration of the ignorance that once was—perhaps it would not be far wrong to say still is—so prevalent in regard to stars.

When a mist, due to the beginning of condensation, forms over the sky the smaller stars cease to be visible, while the brighter ones shine dimly with a blur (really a faint corona) of light about them, each looking like a small confused cluster of stars. Hence the idea, as above expressed, that stars can huddle together at one time—before a rain—and be scattered asunder at another.

There is also some ground for the proverb that declares the number of stars within a lunar halo to be the number of days before a storm, for the nearer the storm the denser the condensation, and therefore the smaller the number of stars seen through it. However, as an entire day is a pretty long unit of time to use in sign forecasting, it would be better simply to say that the fewer the stars within the ring the nearer the rain; though even in this form it is not very trustworthy, owing to the fact that the brighter stars are unevenly distributed.

An entirely different star phenomenon that has given rise to a few proverbs is twinkling, or the irregularities with which they shine. This fluctuation in their light is caused mainly by irregular refraction due to numerous inequalities in the distribution of temperature, such as necessarily accompanies the over and under running of air currents of different temperatures and different humidities, a condition that often precedes a storm. Hence the justification of the prosaic proverb that says:

> "When stars flicker in a dark back-ground rain or snow follows soon."

Wind

"Every wind has its weather."
—*Bacon.*

There are numerous proverbs based on the directions and changes of the wind, but their value, in the main, is only local, except when taken in connection with the height and rate of change of the barometer. However, in middle latitudes the direction of ordinary undisturbed winds is from west to east. Therefore, a radically different direction commonly indicates an approaching, or, at any rate, not very distant, storm. There is, then, some justification for such proverbs as the following:

"When the smoke goes west,
Gude weather is past;
When the smoke goes east,
Gude weather comes neist."

"When the wind's in the south,
The rain's in its mouth."

"The wind in the west
Suits every one best."

Clouds

"And now the mists from earth are clouds in heaven."
—*Wilson.*

The height, extent and shapes of clouds depend upon the humidity and upon the temperature and motion of the atmosphere, and consequently they often furnish reliable warnings of the coming weather.

One proverb correctly says:

"The higher the clouds, the finer the weather."

As already explained, the formation of clouds is caused mainly by cooling due to convection; the rising mass of air expanding and losing heat because of the work it does in lifting the weight that presses upon it. Now the greater the height reached the colder, correspondingly, is the air, and hence we correctly infer that high clouds are formed only at the expense of much cooling and, therefore, that the amount of moisture they contain can not be great enough to produce falling or bad weather.

This proverb must be restricted to stratus and other of the more common clouds. It does not apply to those thin wispy or cirrus clouds, the highest of all, that float from five to eight miles above sea-level, for, as every one knows:

"Mackerel scales and mares' tails
Make lofty ships carry low sails."

Part of the air that forms the strong upward currents near the center of a storm rises to great heights where, in middle latitudes, it gets into the swiftly eastward moving layers that carry it and its ice particles far ahead of the rains. There are other ways by which such clouds can be formed, but that just explained is one of the most common, and as, in this case, they are only the overrunning portion of a storm that is coming on in the same general direction, the proverb just quoted evidently is well founded.

When the air is rather damp and the day is warm great cumulus or thunderhead clouds are apt to form, as a result of strong convection, and produce frequent local showers. Hence the following proverb:

> "When clouds appear like rocks and towers,
> The earth's refreshed by frequent showers."

Another interesting phenomenon, familiar to all who live among the mountains, is the formation of a cloud along the highest ridges, due, of course, to the upward deflection of the wind as it blows against their sloping sides. This mechanical, or forced, convection produces the usual cooling, which, when the air is damp, results in the formation of cloud. Hence the truth of the proverb that tells us:

> "When the clouds are upon the hills,
> They'll come down by the mills."

Sound

> "There is a sound of abundance of rain."
> —*Elijah.*

When the air is full of moisture its temperature tends rapidly to become equalized—the colder places are warmed by condensation and the warmer cooled by evaporation. In this way the atmosphere is freed from the innumerable temperature irregularities that prevail during dry weather, irregularities that, as Tyndal showed many years ago, strongly reflect and dissipate sound. We see, then, that when the air is homogeneous, which it is far more likely to be when damp, it will convey sound much better than it will when filled with inequalities, and hence there is good reason to accept the proverb, and other similar ones, that says:

> "Sound traveling far and wide
> A stormy day will betide."

Not only the hearing, but the seeing as well, is improved by the homogeneity of the atmosphere, and this, too, has its appropriate proverbs of which the following is a good example:

> "The farther the sight, the nearer the rain."

Animals

"Grumphie smells the weather,
An' grumphie sees the wun';
He kens when clouds will gather,
An' smoor the blinkin' sun."

This extravagant tribute to the pig as a weather prophet is typical of a large number of proverbs, though, perhaps, no other animal has been credited with actually seeing the wind.

Doubtless the dampness and change in temperature that commonly precede storms somewhat modify the behavior of many animals, but of the numerous weather proverbs based upon their actions even the few that have any truth to support them have far greater physiological than meteorological interest, and consequently this is not a proper place for their further discussion.

Plants

"Pimpernel, pimpernel, tell me true
Whether the weather be fine or no."

A similar appeal might, with equally good reason, be made to the dandelion, to red clover, to the silver maple, and to numerous other plants, all of which commonly undergo some change, such as the closing of their flowers or an alteration in the attitude of their leaves, at the approach of rain.

These phenomena, however, do not long precede the actual storm, and therefore have but little warning value. They are due to such things as changes in moisture, temperature and sunshine and consequently, while inferior as useful weather signs, are the greatest help to those who would understand plant physiology.

Aches and Pains

"As old sinners have all points
O' th' compass in their bones and joints."
—*Butler.*

It is well recognized, and attested to by a family of proverbs, that those who are annoyed with rheumatic pains, as also the dyspeptic and the neurasthenic, often are more than usually troubled by their ills at the near approach of rainy and generally bad weather. It was for this reason that the wise, though we may suspect not overly joyful, editor, dedicated his almanac to "Torpid Liver and Inflammatory Rheumatism, the most insistent weather prophets known to suffering mortals."

However, such disagreeable signs are not universally available, for, fortunately, there are those who, like Tam O'Shanter, "never mind the storm a whistle." Therefore, while the influences of the weather and its changes on our feelings are worthy of careful study by both the physiologist and the psychologist, such phenomena are of only secondary value as a popular means of weather prognostication. Besides, it is a method not assiduously cultivated—in fact, those who are provided with this particular means to a weather prescience would gladly be rid of it, while those who know it not believe in the old adage that says: "Where ignorance is bliss 'tis folly to be wise."

Miscellaneous

Under this heading one could include a great variety of proverbs—mostly foolish. However, there are two causes, decrease in atmospheric pressure and increase in humidity, that have led to a number of well-founded proverbs, or rather accurate observations, for they are seldom jingled in the typical proverb manner.

Thus we find it stated that the approach of a storm is marked by the rising of water in wells, by the more abundant flow of certain springs, by the bubbling of marshes, by the bad odors of ditches and by various other phenomena, all of which are due to that decrease of atmospheric pressure that ordinarily precedes a storm.

The increase of humidity—favorable to precipitation—is noted by the gathering of moisture on cold objects, the collection of perspiration on our own skins owing to diminished evaporation, and the dampness of many hygroscopic substances. The last effect is illustrated by the packing of salt, the tightening of cordage and of strings of musical instruments, the dull or damp appearance of stone walls and columns, the settling of smoke, and by a number of other similar phenomena, all of which have been appealed to, with more or less justification, as evidence of a gathering storm.

Of course many other weather proverbs, of which those quoted in this article are typical, might be given and explained, but it is hoped that enough from each class have been justified to indicate their importance in all those cases and circumstances where, unfortunately, a weather service can not take the place of weather signs.

SCIENCE AT THE MEDIEVAL UNIVERSITIES

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WITH the growth of interest in science and in nature study in our own day, one of the expressions that is probably oftenest heard is surprise that the men of preceding generations and especially university men did not occupy themselves more with the world around them and with the phenomena that are so tempting to curiosity. Science is usually supposed to be comparatively new and nature study only a few generations old. Men are supposed to have been so much interested in book knowledge and in speculations and theories of many kinds, that they neglected the realities of life around them while spinning fine webs of theory. Previous generations, of course, have indulged in theory, but then our own generation is not entirely free from that amusing occupation. Nothing could well be less true, however, that the men of preceding generations were not interested in science even in the sense of physical science, or that nature study is new, or that men were not curious and did not try to find out all they could about the phenomena of the world around them.

The medieval universities and the school-men who taught in them have been particularly blamed for their failure to occupy themselves with realities instead of with speculation. We are coming to recognize their wonderful zeal for education, the large numbers of students they attracted, the enthusiasm of their students since they made so many hand-written copies of the books of their masters, the devotion of the teachers themselves, who wrote at much greater length than do our professors even now and on the most abstruse subjects, so that it is all the more surprising to think they should have neglected science. The thought of our generation in the matter, however, is founded entirely on an assumption. Those who know anything about the writers of the Middle Ages at first hand are not likely to think of them as neglectful of science even in our sense of the term. Those who know them at second hand are, however, very sure in the matter.

The assumption is due to the neglect of science that came in the seventeenth and eighteenth centuries. We have many other similar assumptions because of the neglect of many phases of mental development and applied science at this time. For instance, most of us are very proud of our modern hospital development and think of this as a great humanitarian evolution of applied medical science. We are very likely to think that this is the first time in the world's history that the building of hospitals has been brought to such a climax of development, and that the houses for the ailing in the olden time were mere refuges, prone to become death traps and at most makeshifts for the solution of the problem of the care of the ailing poor. This is true for the hospitals of the seventeenth and eighteenth centuries, but it is not true at all for the hospitals of the thirteenth and fourteenth and fifteenth centuries. Miss Nutting and Miss Dock in their "History of Nursing"[1] have called attention to the fact that the lowest period in hospital development is during the eighteenth and early nineteenth centuries. Hospitals were little better than prisons, they had narrow windows, were ill provided with light and air and hygienic arrangements and in general were all that we should imagine old-time hospitals to be. The hospitals of the earlier time, however, had fine high ceilings, large windows, abundant light and air, excellent arrangements for the privacy of patients, and in general were as worthy of the architects of the earlier times as the municipal buildings, the cathedrals, the castles, the university buildings and every other form of construction that the late medieval centuries devoted themselves to.

The trouble with those who assume that there was no study of science and practically no attention to nature study in the Middle Ages is that they know nothing at all about the works of the men who wrote in the medieval period at first hand. They have accepted declarations with regard to the absolute dependence of the scholastics on authority, their almost divine worship of Aristotle, their utter readiness to accept authoritative assertions provided they came with the stamp of a mighty name, and then their complete lack of attention to observation and above all to experiment. Nothing could well be more ridiculous than this ignorant assumption of knowledge with regard to the great teachers at the medieval universities. Just as soon as there is definitie knowledge of what these great teachers wrote and taught, not only does the previous mood of blame for them for not paying much more attention to science and nature at once disappear, but it gives place to the heartiest admiration for the work of these great thinkers. It is easy to appreciate then, what Professor Saintsbury said in a recent volume on the thirteenth century.

> And there have even been in these latter days some graceless ones who have asked whether the science of the nineteenth century after an equal interval will be of any more positive value—whether it will not have even less comparative interest than that which appertains to the scholasticism of the thirteenth.

Three men were the great teachers in the medieval universities at their prime. They have been read and studied with interest ever since. They wrote huge tomes, but men have pored over them in every genera-

[1] New York, Putnam, 1908.

tion. They were Albertus Magnus, the teacher of the other two, Thomas Aquinas and Roger Bacon. All three of them were together at the University of Paris shortly after the middle of the thirteenth century. Any one who wants to know anything about the attitude of mind of the medieval universities, their professors and students and of all the intellectual world of the time towards science and observation and experiment, should read the books of these men. Any other mode of getting at any knowledge of the real significance of the science of this time is mere pretense. These constitute the documents behind any scientific history of the development of science at this time.

It is extremely interesting to see the attitude of these men with regard to authority. In Albert's tenth book (of his "Summa") in which he catalogues and describes all the trees, plants and herbs known in his time he observes: "All that is here set down is the result of our own experience, or has been borrowed from authors whom we know to have written what their personal experience has confirmed; for in these matters experience alone can be of certainty." In his impressive Latin phrase "*experimentum solum certificat in talibus.*" With regard to the study of nature in general he was quite as emphatic. He was a theologian as well as a scientist, yet in his treatise on "The Heavens and The Earth" he declared that "in studying nature we have not to inquire how God the Creator may, as He freely wills, use His creatures to work miracles and thereby show forth His power. We have rather to inquire what nature with its immanent causes can naturally bring to pass."[2]

Just as striking quotations on this subject might be made from Roger Bacon. Indeed, Bacon was quite impatient with the scholars around him who talked over much, did not observe enough, depended to excess on authority and in general did as mediocre scholars always do, made much fuss on second-hand information—plus some filmy speculations of their own. Friar Bacon, however, had one great pupil whose work he thoroughly appreciated because it exhibited the opposite qualities. This was Petrus—we have come to know him as Peregrinus—whose observations on magnetism have excited so much attention in recent years with the republications of his epistle on the subject. It is really a monograph on magnetism written in the thirteenth century. Roger Bacon's opinion of it and of its author furnishes us the best possible index of his attitude of mind towards observation and experiment in science.

> I know of only one person who deserves praise for his work in experimental philosophy for he does not care for the discourses of men and their wordy warfare, but quietly and diligently pursues the works of wisdom. Therefore what others grope after blindly, as bats in the evening twilight, this man contemplates in all their brilliancy *because he is a master of experiment.*

[2] "De cœlo et mundo," l, tr. iv., x.

Hence, he knows all of natural science whether pertaining to medicine and alchemy, or to matters celestial or terrestrial. He has worked diligently in the smelting of ores as also in the working of minerals; he is thoroughly acquainted with all sorts of arms and implements used in military service and in hunting, besides which he is skilled in agriculture and in the measurement of lands. It is impossible to write a useful or correct treatise in experimental philosophy without mentioning this man's name. Moreover, he pursues knowledge for its own sake; for if he wished to obtain royal favor, he could easily find sovereigns who would honor and enrich him.

Similar expressions might readily be quoted from Thomas Aquinas, but his works are so easy to secure and his whole attitude of mind so well known, that it scarcely seems worth while taking space to do so. Aquinas is still studied very faithfully in many universities and within the last few years one of his great text-books of philosophy has been replaced in the curriculum of Oxford University, in which it occupied a prominent position in the long ago, as a work that may be offered for examination in the department of philosophy. It is with regard to him particularly that there has been the greatest revulsion of feeling in recent years and a recognition of the fact that here was a great thinker familiar with all that was known in the physical sciences, and who had this knowledge constantly in his mind when he drew his conclusions with regard to philosophical and theological questions.

As for the supposed swearing by Aristotle which is so constantly asserted to have been the habit of these scholastic philosophers, it is extremely difficult in the light of expressions which they themselves use to understand how this false impression arose. Aristotle they thoroughly respected. They constantly referred to his works, but so has every thinking generation ever since. Whenever he had made a declaration they would not accept the contradiction of it without a good reason, but whenever they had good reasons, Aristotle's opinion was at once rejected without compunction. Albertus Magnus, for instance, said: "Whoever believes that Aristotle was a God must also believe that he never erred, but if we believe that Aristotle was a man, then doubtless he was liable to err just as we are." A number of direct contradictions of Aristotle we have from Albert. A well-known one is that with regard to Aristotle's assertion that lunar rainbows appeared only twice in fifty years. Albert declared that he himself had seen two in a single year.

Indeed, it seems very clear that the whole trend of thought among the great teachers of the time was away from acceptance of scientific conclusions on authority unless there was good evidence for them available. They were quite as impatient as the scientists of our time with a constant putting forward of Aristotle as if that settled the scientific question. Roger Bacon wanted the Pope to forbid the study of Aristotle because his works were leading men astray from the study of science, his authority being looked upon as so great that men did not think for themselves but accepted his assertions. Smaller men are always prone to do this, and indeed it constitutes one of the difficulties in the way of advance in scientific knowledge, as Roger Bacon himself pointed out.

These are the sort of expressions that are to be expected from Friar Bacon from what we know of other parts of his work. His "Opus Tertium" was written at the request of Pope Clement IV., because the Pope had heard many interesting accounts of what the great thirteenth-century teacher and experimenter was doing at the University of Oxford, and wished to learn for himself the details of his work. Bacon starts out with the principle that there are four grounds of human ignorance. These are, "first, trust in inadequate authority; second, that force of custom which leads men to accept without properly questioning what has been accepted before their time; third, the placing of confidence in the assertions of the inexperienced; and fourth, the hiding of one's own ignorance behind the parade of superficial knowledge, so that we are afraid to say I do not know." Professor Henry Morley, a careful student of Bacon's writings, said with regard to these expressions of Bacon:

> No part of that ground has yet been cut away from beneath the feet of students, although six centuries have passed. We still make sheep-walks of second, third and fourth, and fiftieth hand references to authority; still we are the slaves of habit, still we are found following too frequently the untaught crowd, still we flinch from the righteous and wholesome phrase "I do not know" and acquiesce actively in the opinion of others that we know what we appear to know.

In his "Opus Majus" Bacon had previously given abundant evidence of his respect for the experimental method. There is a section of this work which bears the title Scientia Experimentalis. In this Bacon affirms that "without experiment nothing can be adequately known. An argument may prove the correctness of a theory, but does not give the certitude necessary to remove all doubt, nor will the mind repose in the clear view of truth unless it finds its way by means of experiment." To this he later added in his "Opus Tertium": "The strongest argument proves nothing so long as the conclusions are not verified by experience. Experimental science is the queen of sciences, and the goal of all speculation."

It is no wonder that Dr. Whewell in his "History of the Inductive Sciences" should have been unstinted in his praise of Roger Bacon's work and writings. In a well-known passage he says of the "Opus Majus":

> Roger Bacon's "Opus Majus" is the encyclopedia and "Novum Organon" of the thirteenth century, a work equally wonderful with regard to its wonderful scheme and to the special treatises by which the outlines of the plans are

filled up. The professed object of the work is to urge the necessity of a reform in the mode of philosophizing, to set forth the reasons why knowledge had not made greater progress, to draw back attention to the sources of knowledge which had been unwisely neglected, to discover other sources which were yet almost untouched, and to animate men in the undertaking of a prospect of the vast advantages which it offered. In the development of this plan all the leading portions of science are expanded in the most complete shape which they had at that time assumed; and improvements of a very wide and striking kind are proposed in some of the principal branches of study. Even if the work had no leading purposes it would have been highly valuable as a treasure of the most solid knowledge and soundest speculations of the time; even if it had contained no such details it would have been a work most remarkable for its general views and scope.

As a matter of fact the universities of the middle ages, far from neglecting science, were really scientific universities. Because the universities of the early nineteenth century occupied themselves almost exclusively with languages and especially formed students' minds by means of classical studies, we in our generation are prone to think that such linguistic studies formed the main portion of the curriculum of the universities in all the old times and particularly in the middle ages. The study of the classic languages, however, came into university life only after the renaissance. Before that the undergraduates of the universities had occupied themselves almost entirely with science. It was quite as much trouble to introduce linguistic studies into the old universities in the renaissance time to replace science, as it was to secure room for science by pushing out the classics in the modern time. Indeed the two revolutions in education are strikingly similar when studied in detail. Men who had been brought up on science before the renaissance were quiet sure that that formed the best possible means of developing the mind. In the early nineteenth century men who had been formed on the classics were quite as sure that science could not replace them with any success.

There is no pretense that this view of the medieval universities is a new idea in the history of education. Those who have known the old universities at first hand by the study of the actual books of their professors and by familiarity with their courses of study, have not been inclined to make the mistake of thinking that the medieval university neglected science. Professor Huxley in his "Inaugural Address as Rector of Aberdeen University" some thirty years ago stated very definitely his recognition of medieval devotion to science. His words are well worth remembering by all those who are accustomed to think of our time as the first in which the study of science was taken up seriously in our universities. Professor Huxley said:

The scholars of the medieval universities seem to have studied grammar, logic and rhetoric; arithmetic and geometry; astronomy, theology and music. Thus their work, however imperfect and faulty, judged by modern lights, it may have been, brought them face to face with all the leading aspects of the many-sided mind of man. For these studies did really contain, at any rate in embryo, sometimes it may be in caricature, what we now call philosophy, mathematical and physical science and art. *And I doubt if the curriculum of any modern university shows so clear and generous a comprehension of what is meant by culture, as this old Trivium and Quadrivium does.*

It would be entirely a mistake, however, to think that these great writers and teachers who influenced the medieval universities so deeply and whose works were the text-books of the universities for centuries after, only had the principles of physical and experimental science and did not practically apply them. As a matter of fact their works are full of observation. Once more, the presumption that they wrote only nonsense with regard to science comes from those who do not know their writings at all, while great scientists who have taken the pains to study their works are enthusiastic in praise. Humboldt, for instance, says of Albertus Magnus, after reading some of his works with care:

> Albertus Magnus is equally active and influential in promoting the study of natural science and of the Aristotelian philosophy. His works contain some exceedingly acute remarks on the organic structure and physiology of plants. One of his works bearing the title of "Liber Cosmographicus De Natura Locorum" is a species of physical geography. I have found in it considerations on the dependence of temperature concurrently on latitude and elevation and on the effect of different angles of the sun's rays in heating the ground which have excited my surprise.

It is with regard to physical geography of course that Humboldt is himself a distinguished authority.

Humboldt's expression that he found some exceedingly acute remarks on the organic structure and physiology of plants in Albert the Great's writings will prove a great surprise to many people. Meyer, the German historian of botany, however, has reechoed Humboldt's praise with emphasis. The extraordinary erudition and originality of Albert's treatise on plants drew from Meyer the comment:

> No botanist who lived before Albert can be compared with him unless Theophrastus, with whom he was not acquainted; and after him none has painted nature in such living colors or studied it so profoundly until the time of Conrad Gessner and Cæsalpino.

These men, it may be remarked, come three centuries after Albert's time. A ready idea of Albert's contributions to physical science can be obtained from his life by Sighart, which has been translated into English by Dixon and was published in London in 1870. Pagel, in Puschmann's "History of Medicine," already referred to, gives a list of the books written by Albert on scientific matters with some comments which are eminently suggestive, and furnish solid basis for the remark that I have made, that men's minds were occupied with nearly the same problems in science in the thirteenth century as we are now, while the conclusions they came to were not very different from ours, though reached so long before us.

This catalogue of Albertus Magnus's works shows very well his own interest and that of his generation in physical science of all kinds. There were eight treatises on Aristotle's physics and on the underlying principles of natural philosophy and of energy and of movement; four treatises concerning the heavens and the earth, one on physical geography which also contains, according to Pagel, numerous suggestions on ethnography and physiology. There are two treatises on generation and corruption, six books on meteors, five books on minerals, three books on the soul, two books on the intellect, a treatise on nutritives, and then a treatise on the senses and another on the memory and on the imagination. All the phases of the biological sciences were especially favorite subjects of his study. There is a treatise on the motion of animals, a treatise in six books on vegetables and plants, a treatise on breathing things, a treatise on sleep and waking, a treatise on youth and old age and a treatise on life and death. His treatise on minerals contains, according to Pagel, a description of ninety-five different kinds of precious stones. Albert's volumes on plants were reproduced with Meyer, the German botanist, as editor (Berlin, 1867). All of Albert's books are available in modern editions.

Pagel says of Albertus Magnus that

> His profound scholarship, his boundless industry, the almost incontrollable impulse of his mind after universality of knoweldge, the many-sidedness of his literary productivity, and finally the almost universal recognition which he received from his contemporaries and succeeding generations, stamp him as one of the most imposing characters and one of the most wonderful phenomena of the middle ages.

In another passage Pagel has said:

> While Albert was a Churchman and an ardent devotee of Aristotle, in matters of natural phenomena he was relatively unprejudiced and presented an open mind. He thought that he must follow Hippocrates and Galen, rather than Aristotle and Augustine, in medicine and in the natural sciences. We must concede it a special subject of praise for Albert that he distinguished very strictly between natural and supernatural phenomena. The former he considered as entirely the object of the investigation of nature. The latter he handed over to the realm of metaphysics.

Roger Bacon is, however, the one of these three great teachers who shows us how thoroughly practical was the scientific knowledge of the universities and how much it led to important useful discoveries in applied science and to anticipations of what is most novel even in our present-day sciences. Some of these indeed are so startling, that only that we know them not by tradition but from his works, where they may be readily found without any doubt of their authenticity, we should be sure to think that they must be the result of later commentators' ideas. Bacon was very much interested in astronomy, and not only suggested the correction of the calendar, but also a method by which it could be kept from wandering away from the actual date thereafter. He discovered many of the properties of lenses and is said to have invented spectacles and announced very emphatically that light did not travel instantaneously but moved with a definite velocity. He is sometimes said to have invented gunpowder, but of course he did not, though he studied this substance in various forms very carefully and drew a number of conclusions in his observations. He was sure that some time or other man would learn to control the energies exhibited by explosives and that then he would be able to accomplish many things that seemed quite impossible under their present conditions.

He said, for instance:

> Art can construct instruments of navigation, such that the largest vessels governed by a single man will traverse rivers and seas more rapidly than if they were filled with oarsmen. One may also make carriages which without the aid of any animal will run with remarkable swiftness.

In these days when the automobile is with us and when the principal source of energy for motor purposes is derived from explosives of various kinds this expression of Roger Bacon represents a prophecy marvelously surprising in its fulfilment. It is no wonder that the book whence it comes bears the title "De Secretis Artis et Naturæ." Roger Bacon even went to the extent, however, of declaring that man would some time be able to fly. He was even sure that with sufficient pains he could himself construct a flying machine. He did not expect to use explosives for his motor power, however, but thought that a windlass properly arranged, worked by hand, might enable a man to make sufficient movement to carry himself aloft or at least to support himself in the air, if there were enough surface to enable him to use his lifting power to advantage. He was in intimate relations by letter with many other distinguished inventors and investigators besides Peregrinus and was a source of incentive and encouragement to them all.

The more one knows of Aquinas the more surprise there is at his anticipation of many modern scientific ideas. At the conclusion of a course on cosmology delivered at the University of Paris he said that "nothing at all would ever be reduced to nothingness" (*nihil omnino in nihilum redigetur*). He was teaching the doctrine that man could not destroy matter and God would not annihilate it. In other words, he was teaching the indestructibility of matter even more emphatically than we do. He saw the many changes that take place in material substances around us, but he taught that these were only changes of form and not substantial changes and that the same amount of matter always remained in the world. At the same time he was teaching that the forms in matter by which he meant the combinations of energies which distinguish the various kinds of matter are not destroyed. In other words, he was anticipating not vaguely, but very clearly and definitely, the conservation of energy. His teaching with regard to the composition of matter was very like that now held by physicists. He declared that matter was composed of two principles, prime matter and form. By *forma* he meant the dynamic element in matter, while by *materia prima* he meant the underlying substratum of material, the same in every substance, but differentiated by the dynamics of matter.

It used to be the custom to make fun of these medieval scientists for believing in the transmutation of metals. It may be said that all three of these greatest teachers did not hold the doctrine of the transmutation of metals in the exaggerated way in which it appealed to many of their contemporaries. The theory of matter and form, however, gave a philosophical basis for the idea that one kind of matter might be changed into another. We no longer think that notion absurd. Sir William Ramsay has actually succeeded in changing one element into another and radium and helium are seen changing into each other, until now we are quite ready to think of transmutation placidly. The Philosopher's Stone used to seem a great absurdity until our recent experience with radium, which is to some extent at least the philosopher's stone, since it brings about the change of certain supposed elements into others. A distinguished American chemist said not long ago that he would like to extract all the silver from a large body of lead ore in which it occurs so commonly, and then come back after twenty years and look for further traces of silver, for he felt sure that they would be found and that lead ore is probably always producing silver in small quantities and copper ore is producing gold.

Most people will be inclined to ask where the fruits of this undergraduate teaching of science are to be found. They are inclined to presume that science was a closed book to the men and women of that time. It is not hard, however, to point the effect of the scientific training in the writings of the times. Dante is a typical university man of the period. He was at several Italian universities, was at Paris and perhaps at Oxford. His writings are full of science. Professor Kühns, of Wesleyan, in his book "The Treatment of Nature in Dante," has pointed out how much Dante knows of science and of nature. Few of the poets not only of his own but of any time have known more. There are only one or two writers of poetry in our time who go with so much confidence to nature and the scientific interpretation of her for figures for their poetry. The astronomy, the botany, the zoology of Albertus Magnus and Thomas Aquinas, Dante knew very well and used confidently for figurative purposes. Any one who is inclined to think nature study a new idea in the world forgets, or has never known, his Dante. The birds and the bees, the flowers, the leaves, the varied aspects of clouds and sea, the phenomena of phosphorescence, the intimate habits of bird and beast and the ways of the plants, as well as all the appearances of the heavens, Dante knew very well and in a detail that is quite surprising when we recall how little nature study is supposed to have attracted the men of his time. Only that his readers appreciated it all, Dante would surely not have used his scientific erudition so constantly.

So much for the undergraduate department of the universities of the middle ages, and the view is absolutely fair, for these were the men to whom the students flocked by thousands. They were teaching science, not literature. They were discussing physics as well as metaphysics, psychology in its phenomena as well as philosophy, observation and experiment as well as logic, the ethical sciences, economics, practically all the scientific ideas that were needed in their generation—and that generation saw the rise of the universities, the finishing of the cathedrals, the building of magnificent town halls and castles and beautiful municipal buildings of many kinds, including hospitals, the development of the Hansa League in commerce and of wonderful manufacturers of all the textiles, the arts and crafts, as well as the most beautiful book-making and art and literature. We could be quite sure that the men who solved all the other problems so well could not have been absurd only in their treatment of science. Any one who reads their books will be quite sure of that.

While most people might be ready then to confess that possibly Huxley was not mistaken with regard to the undergraduate department of the universities, most of them would feel sure that at least the graduate departments were sadly deficient in accomplishment. Once more this is entirely an assumption. The facts are all against any such idea.

There were three graduate departments in most of the universities —theology, law and medicine. While physical scientists are usually not cognizant of it apparently, theology is a science, a department of knowledge developed scientifically, and most of these medieval universities did more for its scientific development than the schools of any other period. Quite as much may be said for philosophy, for there are many who hesitate to attribute any scientific quality to modern developments in the matter. As for law, this is the great period of the foundation of scientific law development, the English common law was formulated by Bracton, the deep foundations of basic French and Spanish law were laid, and canon law acquired a definite scientific character which it was always to retain. All this was accomplished almost entirely by the professors in the law departments of the universities.

It was in medicine, however, where most people would be quite sure without any more ado that nothing worth while talking about was being done, that the great triumphs of graduate teaching at the medieval universities were secured. Here more than anywhere else is there room for supreme surprise at the quite unheard-of anticipations of our modern medicine and stranger still, as it may seem, of our modern surgery.

The law regulating the practise of medicine in the Two Sicilies about the middle of the thirteenth century shows us the high standard of medical education. Students were required to have three years of preliminary study at the university, four years in the medical department and then practise for a year with a physician before they were allowed to practise for themselves. If they wanted to practise surgery, an extra year in the study of anatomy was required. I published the text of this law, which was issued by the Emperor Frederick II. about 1241, in the *Journal of the American Medical Association* three years ago. It also regulated the practise of pharmacy. Drugs were manufactured under the inspection of the government and there was a heavy penalty for substitution, or for the sale of old inert drugs, or improperly prepared pharmaceutical materials. If the government inspector violated his obligations as to the oversight of drug preparations the penalty was death. Nor was this law of the Emperor Frederick an exception. We have the charters of a number of medical schools issued by the popes during the next century, all of which require seven years or more of university study, four of them in the medical department before the doctor's degree could be obtained. When new medical schools were founded they had to have professors from certain well-recognized schools on their staff at the beginning in order to assure proper standards of teaching, and all examinations were conducted under oath-bound secrecy and with the heaviest obligations on professors to be assured of the knowledge of students before allowing them to pass.

It might be easy to think, and many people are prone to do so, that in spite of the long years of study required there was really very little to study in medicine at that time. Those who think so should read Professor Clifford Allbutt's address on the "Historical Relations of Medicine and Surgery" delivered at the World's Fair at St. Louis in 1904. He has dwelt more on surgery than on medicine, but he makes it very clear that he considers that the thinking professors of medicine of the later Middle Ages were doing quite as serious work in their way as any that has been done since. They were carefully studying cases and writing case histories, they were teaching at the bedside, they were making valuable observations and they were using the means at their command to the best advantage. Of course there are many absurdities in their therapeutics, but then we must not forget there have always been many absurdities in therapeutics and that we are not free from them in our day. Professor Richet, at the University of Paris, said not long ago "the therapeutics of any generation is quite absurd to the second succeeding generation." We shall not blame the medieval generations for having accepted remedies that afterwards proved inert, for every generation has done that, even our own.

Their study of medicine was not without lasting accomplishment however. They laid down the indications and the dosage for opium. They used iron with success, they tried out many of the bitter tonics among the herbal medicines, and they used laxatives and purgatives to good advantage. Down at Montpelier, Gilbert, the Englishman, suggested red light for smallpox because it shortened the fever, lessened the lesions and made the disfigurement much less. Finsen was given the Nobel prize partly for rediscovery of this. They segregated erysipelas and so prevented its spread. They recognized the contagiousness of leprosy and though it was probably as wide-spread as tuberculosis is at the present time, they succeeded not only in controlling but in eventually obliterating it throughout Europe.

It was in surgery, however, that the greatest triumphs of teaching of the medieval universities were secured. Most people are inclined to think that surgery developed only in our day. The great surgeons of the thirteenth and fourteenth century, however, anticipated most of our teaching. They investigated the causes of the failure of healing by first intention, recognized the danger of wounds of the neck, differentiated the venereal diseases, described rabies and knew much of blood poisoning, and operated very skilfully. We have their text-books of surgery and they are a never-ending source of surprise. They operated on the brain, on the thorax, on the abdominal cavity, and did not hesitate to do most of the operations that modern surgeons do. They operated for hernia by the radical cure, though Mondeville suggested that more people were operated on for hernia for the benefit of the doctor's pocket than for the benefit of the patient. Guy de Chauliac declared that in wounds of the intestines patients would die unless the intestinal lacerations were sewed up and he described the method of suture and invented a needle holder. We have many wonderful instruments from these early days preserved in pictures at least, that show us how much modern advance is merely reinvention.

They understood the principles of aseptic surgery very well. They declared that it was not necessary "that pus should be generated in wounds." Professor Clifford Allbutt says:

> They washed the wound with wine, scrupulously removing every foreign particle; then they brought the edges together, not allowing wine or anything else to remain within—dry adhesive surfaces were their desire. Nature, they said, produces the means of union in a viscous exudation, or natural balm, as it was afterwards called by Paracelsus, Paré and Wurtz. In older wounds they

did their best to obtain union by cleansing, desiccation and refreshing of the edges. Upon the outer surface they laid only lint steeped in wine. Powders they regarded as too desiccating, for powder shuts in decomposing matters; wine after washing purifying and drying the raw surfaces evaporates.

Almost needless to say these are exactly the principles of aseptic surgery. The wine was the best antiseptic that they could use and we still use alcohol in certain cases. It would seem to many quite impossible that such operations as are described could have been done without anesthetics, but they were not done without anesthetics. There were two or three different forms of anesthesia used during the thirteenth and fourteenth centuries. One method employed by Ugo da Lucca consisted of the use of an inhalant. We do not know what the material employed was. There are definite records, however, of its rather frequent employment.

What a different picture of science at the medieval universities all this makes from what we have been accustomed to hear and read with regard to them. It is difficult to understand where the old false impressions came from. The picture of university work that recent historical research has given us shows us professors and students busy with science in every department, making magnificent advances, many of which were afterwards forgotten, or at least allowed to lapse into desuetude.

The positive assertions with regard to old-time ignorance were all made in the course of religious controversy. In English-speaking countries particularly it became a definite purpose to represent the old church as very much opposed to education of all kinds and above all to scientific education. There is not a trace of that to be found anywhere, but there were many documents that were appealed to to confirm the protestant view. There was a papal bull, for instance, said to forbid dissection. When read it proves to forbid the cutting up of bodies to carry them to a distance for burial, an abuse which caused the spread of disease, and was properly prohibited. The church prohibition was international and therefore effective. At the time the bull was issued there were twenty medical schools doing dissection in Italy and they continued to practise it quite undisturbed during succeeding centuries. The papal physicians were among the greatest dissectors. Dissections were done at Rome and the cardinals attended them. Bologna at the height of its fame was in the Papal States. All this has been ignored and the supposed bull against anatomy emphasized as representing the keynote of medical and surgical history. Then there was a papal decree forbidding the making of gold and silver. This was said to forbid chemistry or alchemy and so prevent scientific progress. The history of the medical schools of the time shows that it did no such thing. The great alchemists of the time doing really scientific work were all clergymen, many of them very prominent ecclesiastics.

Just in the same way there were said to be decrees of the church councils forbidding the practise of surgery. President White says in his "Warfare of Religion with Theology in Christendom," that as a consequence of these surgery was in dishonor until the Emperor Winceslaus, at the beginning of the fifteenth century, ordered that it should be restored to estimation. As a matter of fact during the two centuries immediately preceding the first years of the fifteenth century, surgery developed very wonderfully and we have probably the most successful period in all the history of surgery except possibly our own. The decrees forbade monks to practise surgery because it led to certain abuses. Those who found these decrees and wanted to believe that they prevented all surgical development simply quoted them and assumed there was no surgery. The history of surgery at this time is one of the most wonderful chapters in human progress.

The more we know of the Middle Ages the more do we realize how much they accomplished in every department of intellectual effort. Their development of the arts and crafts has never been equalled in the modern time. They made very great literature, marvelous architecture, sculpture that rivals the Greeks, painting that is still the model for our artists, surpassing illuminations; everything that they touched became so beautiful as to be a model for all the after time. They accomplished as much in education as they did in all the other arts, their universities had more students than any that have existed down to our own time and they were enthusiastic students and their professors were ardent teachers, writers, observers, investigators. While we have been accustomed to think of them as neglecting science their minds were occupied entirely with science. They succeeded in anticipating much more of our modern thought and even scientific progress than we have had any idea until comparatively recent years. The work of the later middle ages in mathematics is particularly strong and was the incentive for many succeeding generations. Roger Bacon insisted that without mathematics there was no possibility of real advance in physical science. They had the right ideas in every way. While they were occupied more with the philosophical and ethical sciences than we are, these were never pursued to the neglect of the physical sciences in the strictest sense of that term.

Is it not time that we should drop the foolish notions that are very commonly held because we know nothing about the middle ages—and therefore the more easily assume great knowledge, and get back to appreciate the really marvellous details of educational and scientific development which are so interesting and of so much significance at this time?

THE SEARCH FOR THE SOUL IN CONTEMPORARY THOUGHT

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THE history of the soul appears to be the history of a vanishing quantity. It has indeed come now to have hardly more than an anthropological interest.[1] In recent text-books of psychology the word "soul" does not occur and the word "mind" seldom or not at all. "Psychology without a soul" is no longer a reproach but a truism. "The soul," as a prominent psychologist recently said, "is as dead as the dodo."

Kant represents the turning point in the history of the soul concept. From Plato to the pre-Kantian dogmatists, the current of philosophic thought through Plotinus, Augustine and Descartes brought the soul into clearer and more definite outline. It was a pure spiritual being, an entity, a real thing, constituting human personality. It was furthermore, an active being, a synthetic creative power, unifying and harmonizing the elements of knowledge. Finally it became a substance, a thinking substance, so picturesquely concrete and definite that it could even be located in a certain corner of the brain.

It is Kant who is supposed to have begun the serious unsettling of these very rigid foundations, but the net results of the Critiques is to establish the doctrine of the soul more firmly than ever. To be sure, the scholastic substantial reality of the soul, its simplicity and immortality, are beyond the ken of theoretical reason, but despite this mild skeptical innovation Kant enlarges the original, creative, synthesizing power of the mind beyond all suspicion. Human personality, indeed, belongs to the realm of "things in themselves," possessing both freedom and immortality.

While this lofty theory of the soul has been perpetuated in German and English idealism, nevertheless it is Kant's skeptical attitude as regards this subject that under the influence of modern empiricism has finally prevailed. Psychology, being a natural science, has nothing to do with Kantian *noumena*. Experience gives us a stream of thoughts, feelings and memory images, but no souls. German materialism, English associationism and American empiricism have all united in suppressing the soul. The late Professor James taught that there is not

[1] Compare Crawley, "The Idea of the Soul."

only no evidence of its existence, but it is a useless conception, its place being adequately supplied by the passing thought or feeling. "Souls," he says, "have worn out both themselves and their welcome."[2]

It would seem, therefore, to the initiate in contemporary psychology that the soul concept is obsolete or at the best obsolescent.

To the more careful student, however, this conclusion turns out to be rather hasty. Further study leads him to a series of interesting discoveries which shake his faith in his first impression. His first trouble may come when he opens Professor Eucken's recent book, "The Problem of Human Life," and reads on page 551, "Man's soul is a fact. Who can deny it? It is indeed the fundamental fact which must take precedence of all others." As he reads further in continental thought, he finds that the evanescence of the word "soul" from contemporary psychology is a phenomenon belonging largely to England and America alone. The Germans freely use the word *Seele*. His second discovery is that, while radical empiricists are carefully explaining that psychology is a natural science and as such has only to do with facts and the only facts are the passing thoughts, feelings and volitions, this attitude is only a measure of extreme caution on the part of a science which has suffered much in the past from its unhappy entanglements with metaphysics and theology and he finds that philosophers, biologists, sociologists and even these same empirical psychologists in their philosophical moods have very little hesitation in positing some theory of the soul to explain facts thrust upon them in their several fields of investigation.

His third discovery is that the psychology of the day has not so much dispensed with the soul concept as substituted merely another word for it, that word being "consciousness." He finds indeed that "consciousness" is very much in vogue. The word stares at him from every page of the text-books which studiously avoid the "soul" and the "mind." Current psychological journals abound in articles examining into the nature of consciousness, extolling its psychological, sociological and even cosmic significance. We are indeed confronted with the following interesting situation: While on the one hand, the soul has lapsed from psychological science and the psychologist is busily engaged in studying *processes* and *behavior,* on the other hand there never was a time in the history of science when from every quarter came so many assurances that consciousness is a biologic, psychologic, social and cosmic factor of the most profound importance.

Our inquiring student, therefore, will naturally ask how the concept of consciousness differs from the old concept of the soul, whether the new one is better than the old, and, if so, whether, after all, the loss of the soul is serious if something better has come to take its place.

If we turn to the standard text-books of psychology, we find that

[2] James, "A Pluralistic Universe," p. 210.

the word "consciousness" is often loosely used and has a variety of meanings. More commonly it is used in one of two meanings. It means first "the mind's awareness of its own processes,"[3] or "the immediate knowledge which the mind has of its sensations and thoughts."[4] In this sense it is a kind of subject-object consciousness and involves distinction, contrast, polarity, and may have arisen in the process of evolution in the stress and tension experienced by an organism in adjusting itself to new and adverse situations.[5] In the second sense, however, "consciousness is identified with mind, and 'conscious' with 'mental.'"[6] Mind and consciousness mean the same thing. To be conscious is just to have a mental process. Now it is in this second sense, as we are told, that the word is correctly used in psychology.[7]

It would seem then that we have merely a new *word* for the old *thing,* for it is clearly stated that the word "consciousness" when correctly used means just the same as the word "mind" and to be conscious is to have a mental or psychical experience. Consciousness is just a comprehensive word to designate all sorts of "psychical" processes, such as thoughts, feelings, volitions, impulses, pains and pleasures. Now the word "psychical" is wholly orthodox in modern psychology. It is sometimes used in a broader sense than the word "mental" and is expressly applied to any phenomenon which is subject matter of the science. But the English word "soul," corresponding to the Greek ψυχή is the noun correlative with the adjective "psychical." Consciousness, therefore, when "correctly" used, is not the consciousness indicated by the etymology of the word nor the subject-object consciousness of Locke, Dugald Stewart and historical psychology, but just a new word, a synonym for soul, having an old form and another meaning.

Now the reason why a new word was needed is simply this. The words "soul" and "mind," owing to their metaphysical and theological associations, have become obnoxious. The word "soul" in particular suggests something over and above our mere inner experiences, some "substance," which may perhaps leave the body and be "immortal." Interest in "immortality" has waned and the notion of "substance" adds nothing to our notion of psychological phenomena. Hence, owing to quite fortuitous reasons, the good old Saxon word "soul," which has indeed a much more spotless history than the word "consciousness," has been sacrificed. This perhaps was inevitable, but it is unfortunate that the new word is one having rightfully another

[3] Titchener, "A Text Book of Psychology," p. 17.

[4] Dugald Stewart, quoted by Titchener, *loc. cit.*

[5] Compare Bawden, "The Psychological Theory of Evolution," *Journal of Comparative Neurology*, Vol. XI., No. 3, p. 263.

[6] Titchener, *op. cit.*, p. 18.

[7] *Idem.*

meaning, leading to endless confusion and misunderstanding. Psychologists themselves deplore the ambiguities of the word "consciousness." "There is no philosophical term at once so popular and so devoid of standard meaning. How can a term mean anything when it is employed to connote anything and everything, including its own negation?"[8] "For the sake of clearness, terms like mind and psychosis will be substituted for 'consciousness,' owing to its ambiguity."[9] Of consciousness Avenarius says, "It would be better to give up entirely so treacherous a term."[10]

In the following illustrations of the emphasis placed upon consciousness in recent science, it should be remembered, then, that the word is used either as quite synonymous with the older words "mind" and "soul," or else, as is quite commonly the case, it is used in the sense of an indefinite, not wholly known, psychic factor of life and progress. In this latter sense the word soul, if it were permitted to use it, would be still more appropriate. The careful reader in contemporary psychological and biological science will make the further interesting discovery that the word "consciousness" is also used in the original and more proper sense, as subject-object consciousness or self-consciousness, and that it is usually so used by those writers who are engaged in showing that consciousness is an evolutionary product of life and organization, while, on the other hand, those now numerous writers and investigators who believe that consciousness is a primitive datum or deep underlying force of life, organization and progress, use the word in one of the other two senses just mentioned.

Let us take, then, a few illustrations of the emphasis which recent science is putting upon consciousness as a world factor of primary importance. Let it be borne in mind that until recently there were few outside the ranks of idealistic philosophers to dispute the prevalent belief that mechanical laws are sufficient to account for every phase of human life, including mental and moral phenomena; that at certain stages of organic evolution consciousness appears as a kind of by-product and has no agency in the life drama itself, and that it is not necessary to take any causal account of it in explaining life in its physiological, psychological or social aspects. With this view compare that of many representative present-day psychologists who hold that consciousness, although itself perhaps a product of evolution, has become a factor in evolution of the very first importance, changing not only the very face of the earth, but changing the direction of evolution itself. One writer says:

[8] Perry, "Conceptions and Misconceptions of Consciousness," *Psychological Review*, Vol. 11, p. 282.

[9] Crawley, "The Idea of the Soul," p. 58.

[10] "Am besten wärs man gäbe einen so verfänglichen Ausdruck ganz auf." Quoted by W. T. Bush, *Journ. Phil., Psych. and Sci. Meth.*, Vol. II., p. 561.

> I believe we need to work further on this problem of evolution until we see that in its consummation organic evolution passes into a form of adjustment in which the inner world with its conscious pattern for changes in the outer world is more important than any form of objective selection which can be discovered. . . . Consciousness is the essential fact in human life, as I have attempted to show. What man does with his environment depends upon consciousness. That phase of individuality which is important enough to change the type of evolution certainly can not be described as non-existent or as merely resolvable into its elements.[11]
>
> Some day the historian of thought will write it down as one of the curious fallacies of immature science that certain physiologists, biologists and even psychologists were satisfied to call their own personalities mere by-products, without essential significance in the world, just because they did not find consciousness capable of description in the regular scientific formulas adapted for the discussion and explanation of external reality. One hardly knows how to find phrases in which to answer those who hold consciousness to be less real and potent than physical forces.[12]

These writers refuse to limit the idea of causality in such a way as to exclude the conspicuous fact that the mind is a veritable cause. By its peculiar and exclusive power of ideal reconstruction of experience, it becomes a tremendous new force in the world, bending material forces to its will, first picturing then realizing ever higher marks in science, art, literature, justice and the progress of civilization in general. Consciousness certainly is potent, and if potent, then, according to pragmatism, true and real.

Thus far, then, it begins to appear that, even granting that consciousness may be a product of evolution, nevertheless its potency and hence its reality might become the ground for what may be called a re-discovery of the soul. But there is a tendency not only to recognize the reality and potency of consciousness, but to carry it farther and farther back in the evolutionary process, if not to make it a primitive datum. The old "orthodox" descent, starting with chance variation and natural selection and coming down through simple irritability and sensory-motor reflexes, till finally consciousness is evolved, no longer satisfies either psychologists or biologists. Many believe that all so-called reflex acts, including instincts, were once conscious acts. The fact that conscious actions tend to become automatic might, however, easily be misunderstood. It does not point to any displacement or impoverishment of consciousness. Such apparent displacement "is for the sake of its own inherent ends, being the *conditio sine quâ non*, of its further extension and enrichment."[13] Human development does

[11] C. H. Judd, "Evolution and Consciousness," *Psychological Review*, Vol. XVII., 2, pp. 90, 93.

[12] C. H. Judd, "Psychology," p. 62. Compare Edward M. Weyer, "A Unit Conception of Consciousness," *Psychological Review*, XVII., 5, p. 318.

[13] Norman Smith, *Philosophical Review*, Vol. XVII., p. 334, reviewing Mitchell's "Structure and Growth of the Mind."

not seem to be in the direction of instincts exhibited by bees and ants, but in quite another, namely, that of self-reflective intelligence.[14]

Something, then, more or less of a psychical nature, call it soul, call it consciousness, call it sensibility, call it vital impulse or vital force, or call it merely a psychic factor of progress, has been a primary factor in organic evolution. "Life has preceded organization" and "consciousness was coincident with the dawn of life." It has been a kind of "*primum mobile*" of organic structure. Something like "effort" has preceded upward changes.[15] Consciousness is not a function of organization and is not an epiphenomenon. It is a bionomic factor of the utmost importance. It is of the highest use in adapting organism to environment. It changes the direction of energy. It intervenes between sensation and reaction in the realization of ends. "A frank unbiased study of consciousness must convince every biologist that it is one of the fundamental phenomena of at least animal life, if not, as is quite possible, of all life." "Consciousness is a conspicuous, a commanding factor of adjustment in animals."[16]

Whether consciousness is thought of as a form of energy comparable with heat and electricity,[17] or as an independent dimension of reality,[18] or as some original and primary correlative of energy,[19] nevertheless it is certain that it is a reality, a potency, a factor second to none other, physical or metaphysical.

Even the biological laboratory is offering a suggestive support to the soul hypothesis. If one chooses to accept the theory, as old as the history of thought, that something of a psychical nature bridges the gap, still unspanned by natural science, between the organic and the inorganic, his belief gains new and unexpected support from recent biological studies. So much scorn has been cast upon the theory of vitalism that its recent renewal by a whole school of able German biologists is exceedingly significant. Driesch bases his vitalistic conclusions upon the most careful and long-continued laboratory researches. He discards the machine theory of the origin of life.

> No kind of causality based upon the constellations of single physical and chemical acts can account for organic individual development; this development is not to be explained by any hypothesis about configuration of physical and chemical agents. . . . Life, at least morphogenesis, is not a specialized arrange-

[14] Compare Bergson, "L'evolution créatrice," Chapitre II.

[15] Cope, "Primary Factors of Organic Evolution," p. 508 ff.

[16] Chas. S. Minot, "The Problem of Consciousness in its Biological Aspects," *Science*, N. S., Vol. XVI., No. 392, pp. 17, 19.

[17] Compare Ostwald, *Monist*, Vol. 17, p. 514, and Grunewald, "Zur Energetik des Lebens," *Annalen der Naturphilosophie*, IX., 237.

[18] Compare Boodin, "Consciousness and Reality," *Journ. Phil., Psych. and Sci. Meth.*, Vol. V., No. 7, p. 173.

[19] Compare Minot, *loc. cit.*

ment of inorganic events; biology, therefore, is not applied physics and chemistry: life is something apart, and biology is an independent science.[20]

By giving to this elemental directive factor the name "entelechy" and by applying to it in its formative aspect the further name "psychoid," Driesch implies and indeed repeatedly affirms not only its reality, but its analogy with what we call the psychical.

Nägeli's "Vervollkomnungsprinzip," or inherent factor tending towards progress in evolution, Noll's "Morphæsthesia," or feeling for form which plants are said to possess, Korschinsky's "special tendency to advance," Cope's "archæsthetism," "the inherent driving force," "the inner law of development," "the inner directive force," of other biologists,[21] all have a strangely psychological sound. It is of course true that these positions are vigorously contested by biologists of the orthodox schools, who speak of the "recrudescence" of vitalism. But protests such as the above against the sufficiency of mechanical laws to account for progress in evolution are becoming so many and from such high sources that no psychologist who would postulate a psychic factor of progress, constituting, it may be, the soul of plants, animals and man, need any longer hesitate for fear of censure from the biological camp.

But if vitalism is objectionable, it should be remembered that the choice is by no means between that and the sufficiency of the Darwinian theory of chance variation and natural selection. The number of biologists who accept neither of these solutions of the evolutionary problem is of course very great. If one accepts, for instance, the mutation theory of de Vries, it should be remembered that the difficulties of explaining the *cause* of the adaptive variations upon which Darwinism depends are greatly increased in explaining the cause of the sudden and rapid mutations in the system of de Vries. In general one may say that the belief in orthogenesis, or development in certain definite directions, has to a considerable extent superseded Darwin's theory of development, and with the increasing belief in orthogenesis comes an increasing demand for some yet unknown factor determining the direction of development, and while there are many theories proposed to account for such development without the introduction of any teleological or psychic factor, nevertheless it appears that those who wish to renew the time-honored hypothesis of some such factor are now heard with increasing respect.

From facts such as these we see not only that many workers in science are busily engaged in the search for the soul, but also that the prospects are reasonably good that they will find it.

But let us return to the psychologists. Another aspect of the tend-

[20] Driesch, "The Science and Philosophy of the Organism," 1907, p. 142. Compare G. Wolff, "Beiträge zur Kritik der Darwin'schen Lehre."

[21] See Kellogg, "Darwinism To-day," pp. 277, 278.

ency to glorify the mind and to give to it, or to some part of it, or to something like it, a leading rôle on the stage of events is seen in the voluntaristic movement. The voluntarists do not necessarily hold to any old-fashioned notions of the will as real. The tendency in voluntarism is a part of the general tendency to believe that processes are more real than things. Our volitions, therefore, being obviously processes, movements, springs, are better types of psychical reality than sensations or ideas. So on every side we find emphasis laid upon will, impulse, instinct, inner activity, mental initiative and attention. "Inner activity" is spoken of in the case of the lowest animal organisms and even of plants. In studying animal behavior, we learn that the earliest movements are not mere reflexes, but a series of "trial movements of the most diverse character and including at times practically all the movements of which the animal is capable."[22] Likewise the reflex mechanical theory fails to account for the "tropisms" of plants. Although few biologists would explain the "tropisms," or perhaps even the "trial" movements of the microorganisms as psychical, nevertheless it is admitted that they are forms of inner activity and not reflexes, and it is hard for psychologists not to associate them with such human phenomena as attention, impulse and initiative. The suggestive term "restlessness" has been used to characterize these simple forms of self-activity.[23] Something like an eternal restlessness seems to be present in every form of living matter from the microorganism with its incessant "trial" movements to the adult human being with his exhaustless aspirations. It manifests itself in the variations and mutations of plants and animals, in the "try, try again" movements of the creeping child, in the play of youth,[24] in the inner stirrings, passionate longings and ceaseless activities of the adolescent, and in the inventions, explorations, ambition and progress of the mature man of culture. Despite every effort of naturalism to explain the power of voluntary and sustained attention, the apparent freedom of the will, and the art impulse, there remains in these phenomena an unexplained residue which apparently depends upon this inherent principle of self-activity.

The term "restlessness," however, suggestive as it may be, does not quite rightfully express the character of this profound principle of inner activity which eludes all scientific analysis. It is something more than restlessness and something less than aspiration. All attempts to account for progress, whether cosmic or human, without the assumption of some such deep psychic factor, have failed. There is apparently in man, as in nature, a *spring* of progress, an upward and

[22] Jennings, "Behavior of the Lower Organisms," p. 280.
[23] Royce, "Outlines of Psychology," Chaps. VII. and XIII.
[24] *Idem*, p. 319.

forward impulse, an effort, a ceaseless striving, a will to produce always a more perfect form, a better function. It is this tropic, restless, aspiring force, this psychic factor of progress, that prompts us evermore to invent a new way, a shorter cut, a better method, and leads to the steady and inevitable raising of moral and political standards. To speak of this factor as a "force" or "energy" is merely to use a category taken from material science. To say that it is "teleological" and works towards "ideals" is to interpret it in terms of narrow human experience. It matters little what we call it, but if we call it "mind" or "soul," it suggests no longer a "substance," no static quantity, nor yet just the sum total of our conscious life—but rather a sort of bubbling spring, a profound source, from which upwells the entire organic world, culminating now in the whole mass of human achievement and aspiring to some ever higher conscious or unconscious goal.

PROGRESS IN CONTROL OF PLANT DISEASES

By Dr. F. L. STEVENS

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PLANTS are subject to disease. As in the human being these diseases decrease vigor and productiveness of the organism or cause death. An attack upon valuable plant products such as ripe fruit, tubers and root crops, and mature timber may result in depreciation in value or even entire loss of the product. The rot of apples upon the tree or in the bin, the common blue mold seen upon lemons and oranges, the wide-spread blight of pear and apple twigs (Fig. 1) are familiar examples of plant disease.

In the early years of American history these afflictions were regarded as natural and inevitable, but during the last three or four decades scientific study has shown that rots, blights, molds, mildews, rusts, smuts, etc., are true diseases; that they do not constitute any part of the normal life stages of the plant affected. That they are caused by living parasites and, moreover, that they are often preventable.

Plant diseases have increased largely in number and destructiveness during recent years. This is due in part to the migration of disease from county to county and state to state; in part to the cultivation of weak or susceptible varieties and in part to long continued cropping in a given region, thus affording opportunity for the plant pests, which may at first have been weak and unimportant, to become thoroughly established and aggressive.

The asparagus rust, which has in some states nearly prohibited asparagus culture, offers an excellent example of migration in its progressive westward march across our continent. This invasion seems to have occupied the years between 1896 and 1902 since the rust was first noted at New Jersey in 1896, South Carolina 1897, Michigan 1898, Illinois 1899, Dakota, Nebraska and Texas 1900, California 1901 or 1902.

The destructive pear blight, our worst pear disease, made a similar journey, starting from the neighborhood of the Hudson valley, near the beginning of the last century, reached the Rockies sometime after 1886 and arrived in California about 1895.

Diseases have come to America from Europe. Grape anthracnose, cabbage club root, potato wart (Fig. 2), are noteworthy examples; similarly, serious American plant diseases such as potato blight, grape black rot, grape downy mildew and powdery mildew have made the European tour or even the world tour "personally conducted" under some unwitting guides.

FIG. 1. PEAR BLIGHT, healthy and diseased twigs.

The chestnut bark disease (Fig. 3) illustrates well the rapid and destructive invasion that is possible in case of new diseases. First noted in 1904 by Murrill in New York, and now well known in New York, New Jersey, Delaware, Connecticut, Rhode Island, Maryland and Virginia, it is rapidly spreading in every direction (Fig. 4). In Brooklyn 16,695 trees were killed on 350 acres, and the loss in and about New York city is placed at five to ten million dollars. The chinquepin and chestnut alone are susceptible. The attack is made upon the bark through wounds, but twigs and leaves are not directly affected. From the point of attack the disease spreads in all directions until the diseased parts meet on the opposite side of the branch, thus girdling the twig and killing it.

Sometimes it happens that a newly introduced disease causes much loss in its first years and later sinks to comparative insignificance. Such was the history of the carnation rust which about 1892 caused the loss of entire houses of plants, but which in a few years spent its force until it is now regarded as a disease of no unusual menace. In other instances imported diseases continually remain serious, as have the numerous grape diseases introduced into Europe from America and from Europe into America.

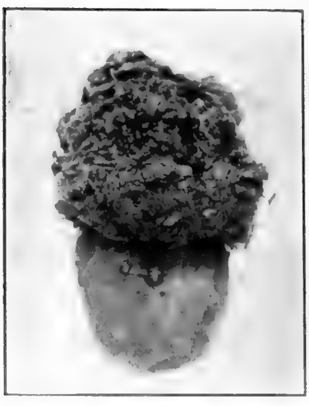

FIG. 2. A POTATO HALF DESTROYED BY "WART DISEASE"; the large "warty" outgrowth is soft and rapidly decaying.

The diseases mentioned in Diagram I. are nearly all of great destructiveness. The potato blight is that which caused the famous potato famine in Ireland in 1845, in which year it swept Great Britain as well as much of Europe and America with a

FIG. 3. LARGE CHESTNUT TREES KILLED BY THE BARK DISEASE.

wave of disease. It to-day causes loss estimated at $36,000,000 annually in the United States. New York alone has incurred a loss of $10,000,000 in one year.

The asparagus rust prohibited successful asparagus culture in several states and threatened that industry in California, where the crop occupies yearly over 7,000 acres of land, until means of control were devised by scientific men. The rice smut was recognized in its

FIG. 4. MAP SHOWING THE DISTRIBUTION OF THE CHESTNUT BARK DISEASE. Black shows area of severe infection; round dots, presence of disease prior to 1909; + indicates the spread of the disease during 1909. After Metcalf.

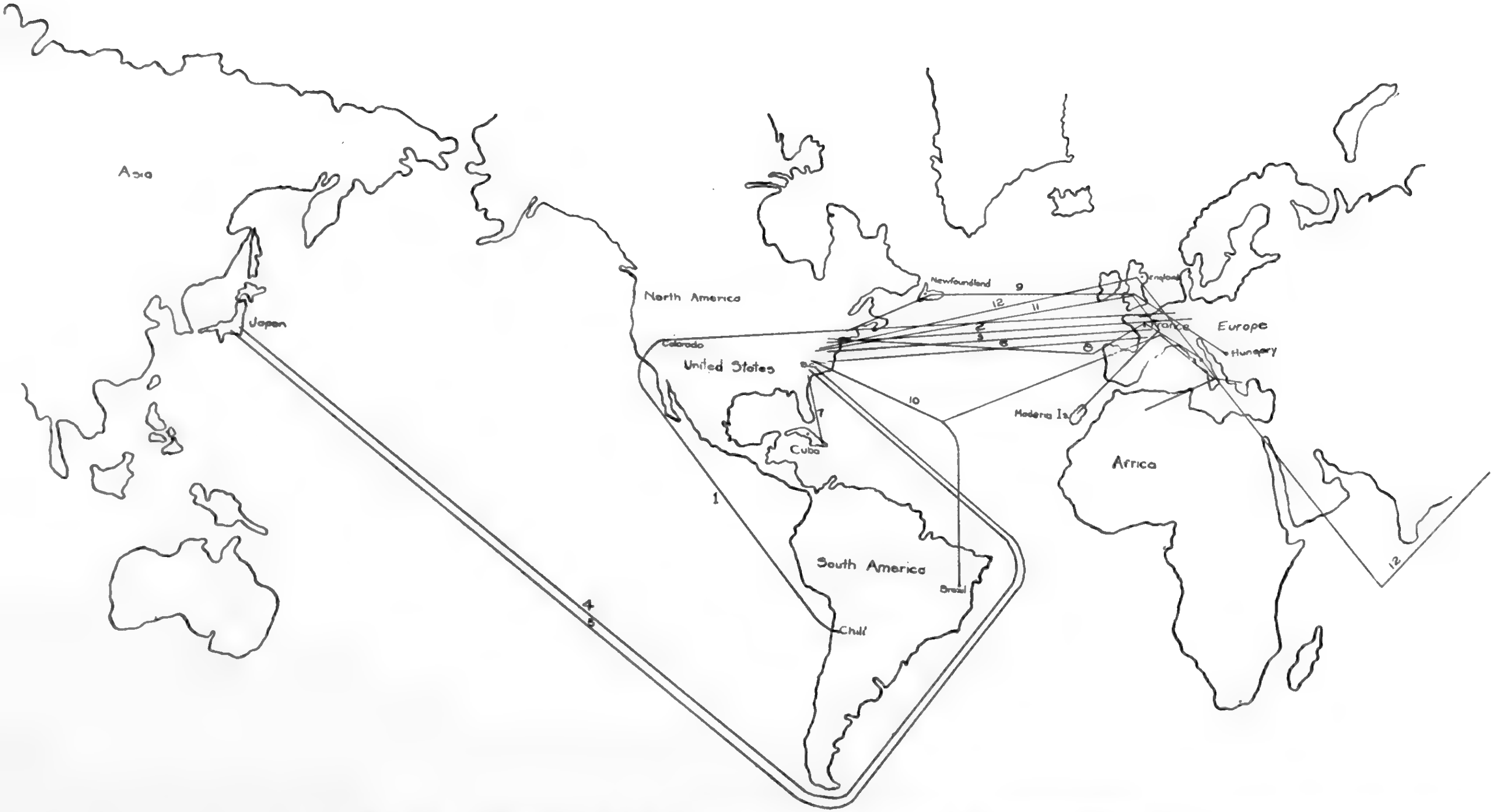

DIAGRAM 1. ILLUSTRATING THE INTER-CONTINENTAL MIGRATION OF PLANT DISEASES.

No. 1, potato blight: Chili-Colorado-Europe. No. 2, asparagus rust: Europe, 1805; New Jersey, 1896, South Carolina, 1897; Michigan, 1898; Illinois, 1899; Dakota, Nebraska and Texas, 1900; California, 1901. No. 3, potato cercosporose: Europe, 1854; United States, 1903. No. 4, rice smut: Japan-South Carolina, 1898. No. 5, sorghum smut: Japan-United States, 1884. No. 6, grape anthracnose: Europe-America, 1880, or earlier, now widespread. No. 7, cucumber downy mildew: Cuba, 1868; United States, 1889. No. 8, grape black rot: North America, early; France, 1885; Italy and the Caucasus, 1898. No. 9, potato wart: Hungary, 1896; England, 1900; Newfoundland, 1909; Boston and New York, 1910. No. 10, grape downy mildew: America early; France, 1873; The Rhineland, Savoy and Italy, 1879; The Tyrol and Algiers, 1880; Portugal and Greece, 1881; Alsace, 1882; the Caucasus 1887; Brazil, 1890. Now known in all countries except Australia. No. 11, grape powdery mildew: United States, early; England, 1845; Belgium and France, 1848; all Europe, 1849; Madeira, 1852. Known everywhere now. No. 12, chrysanthemum rust: Japan-England, 1895; ...

DIAGRAM 2. SHOWING INTER-STATE MIGRATION OF SOME IMPORTANT DISEASES.
1, asparagus rust: New Jersey, 1896; South Carolina, 1897; Michigan, 1898; Illinois, 1899; Dakota, Nebraska, Texas, 1900; California, 1901. 2, fire blight: the Hudson, 1792; California, 1895-7, 3, peach yellows: Philadelphia, 1806; Ontario, Michigan, Illinois, Maine, 1886.

first encroachment in South Carolina and an agressive campaign against it with remedies which had recently proved efficient against smuts of other cereals checked it and completely subjugated it, so that it is no longer known in the Palmetto State. The cucumber mildew, which causes blanched spots on the leaves and often entire loss of crop, has rendered unprofitable the culture of cucumbers and cantaloupes in many sections. The two grape mildews are notorious in their destructiveness and have driven vineyardists to large expense in spraying or sulphuring.

Perhaps the most striking importation is that of the potato wart. This disease causes large unsightly knotty excrescences on the potato, rendering them worthless. It was first reported in England in 1902, found its way to Newfoundland, and it is known that two consignments of Newfoundland potatoes, probably infected, were shipped last year, one to New York, one to Boston. The spread of this disease in our states is an event to be predicted with confidence, especially as many sections of the country depend upon New England for their seed potatoes.

The large increase in aggressiveness of plant diseases has been met by a campaign of increased knowledge leading to new modes of subjugation. Though a few plant diseases are mentioned in early writings, (II. Chronicles 6–28, Shakespear's King Lear, III., Sc. 4; I. Kings 8–37; Moses 28, 22), the real significance of their presence, their nature and causes may be said to have been first recognized between the

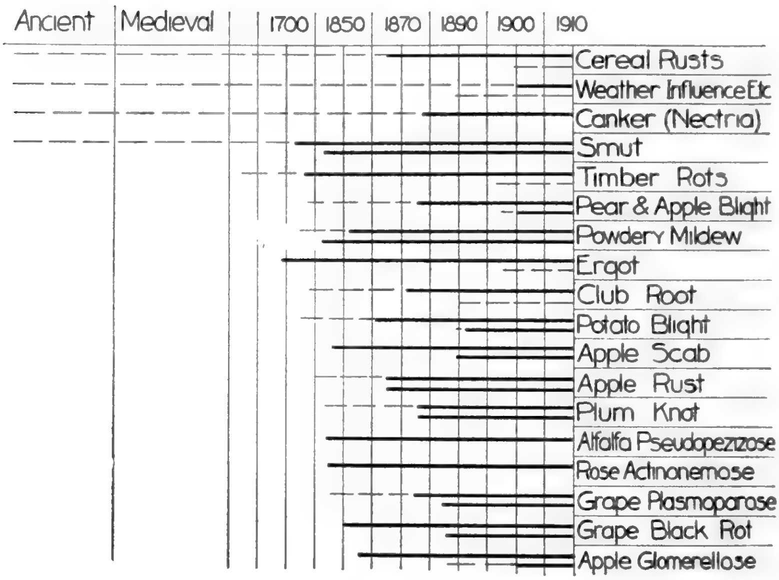

TABLE I

TABLE I (*Continued*)

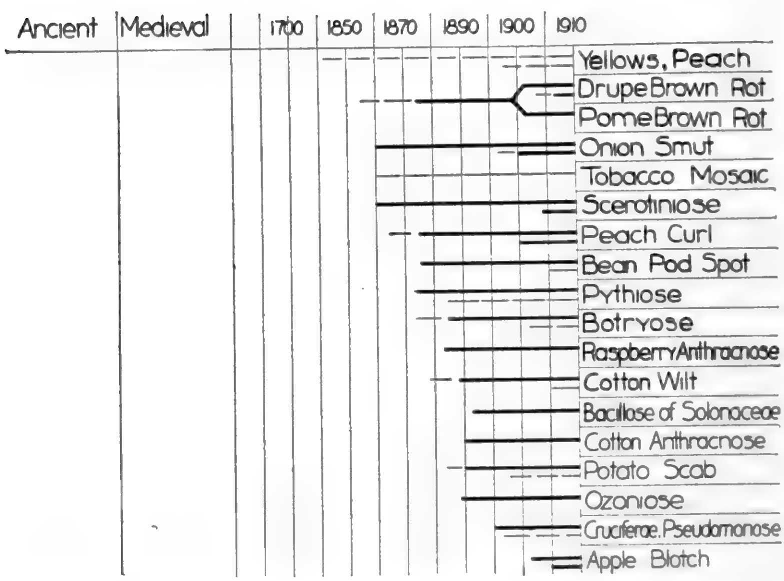

TABLE I. SHOWING ADVANCE IN KNOWLEDGE REGARDING SOME OF THE CHIEF PLANT DISEASES. The broken upper line indicates vague or indefinite knowledge; the solid line definite knowledge. The lower broken line indicates partial but unsatisfactory knowledge concerning treatment; the solid line the possession of facts sufficient for satisfactory treatment.

years 1846 and 1864, notwithstanding the fact that the first sulphur treatment for powdery mildew was recommended in 1821 and the first seed treatment for smuts was discussed in 1807.

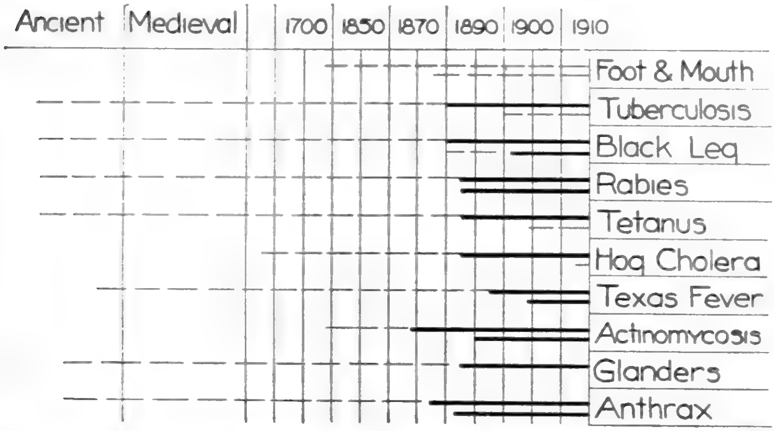

TABLE II. SHOWING ADVANCE IN KNOWLEDGE REGARDING SOME OF THE CHIEF DISEASES OF DOMESTIC ANIMALS. The broken upper line indicates vague or indefinite knowledge; the solid line definite knowledge. The lower broken line indicates partial but unsatisfactory knowledge concerning treatment; the solid line the possession of facts sufficient for satisfactory treatment.

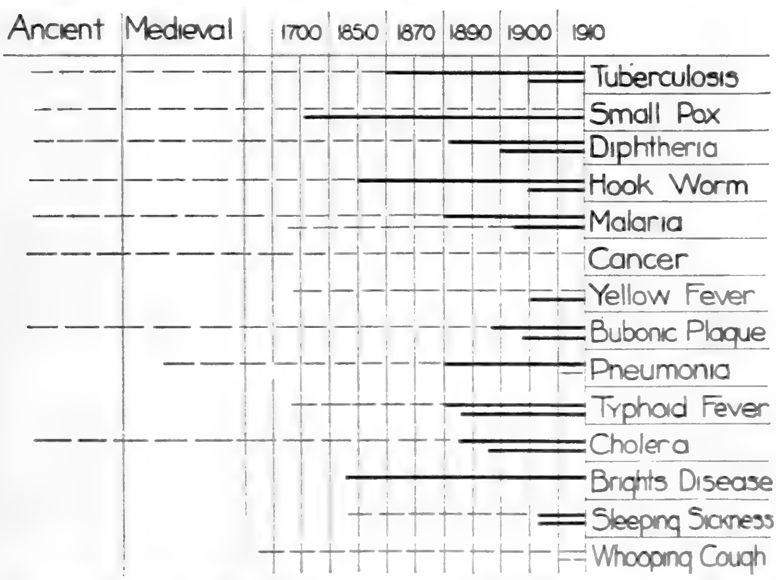

TABLE III. SHOWING ADVANCE IN KNOWLEDGE REGARDING SOME OF THE CHIEF HUMAN DISEASES. The broken upper line indicates vague or indefinite knowledge; the solid line definite knowledge. The lower broken line indicates partial but unsatisfactory knowledge concerning treatment; the solid line the possession of facts sufficient for satisfactory treatment.

The most important advance in prophylactic procedure came with the introduction of the Bordeaux mixture, a compound of lime, bluestone and water, by Millardet in 1885. Since that date the battle has waged fiercely with successive conquests for plant pathology. Now many of the most important diseases are well understood and many successful modes of treatment have been devised.

Some of these with their most significant dates are represented in Table I.

During the seventies there were only two or three investigators in plant pathology in America. This number rapidly increased until between 1888 and 1900 over 4,000 papers upon this subject appeared. Only a few dozen economic plant diseases had been even cursorily described prior to 1880, while to-day a total of over 500, more than 250 of them serious, have been investigated. Countless diseases of wild plants also are now known more or less completely.

To enable comparison of the real advance made in plant pathology with the advances made in the sister fields of veterinary medicine and human medicine, two tables are given summarizing the history of these two fields as regards a few of the most important diseases (tables II. and III.).

That plant pathology has made such a relatively good showing notwithstanding her tardy start is due to the late influence of the germ theory of disease in all of these fields.

With the continual increase of plant diseases in both number and aggressiveness every effort of the plant pathologist will be required to increase the efficiency of treatment. So also is there great need of a public opinion favoring rational plant sanitation. The chief diseases now prevalent as well as those which are liable to invade any section in the near future should be known to all plant producers. Especially needed are laws properly enforced to restrict the migration of diseases.

THE SERVICES AND REWARDS OF THE OLD GREEK VOLUNTEER

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FROM Athens to America; from Marathon, Salamis and Chæronea to Bunker Hill, Gettysburg and Manila Bay, greatness and gratitude have been inseparable terms in national glory. From the earliest history of soldiery down to our day, martial renown and even long lease of national life have been won by those nations only which asked the greatest sacrifice and bestowed the greatest honors and rewards upon their citizen-soldiers.

The prestige of Roman arms has gone up and down the world, but the people of Greece showed a devotion to their warrior braves almost unequalled in the annals of civilization. We are apt to feel that the victories of Greece were those of the brain and not those of the sword, and, in her signal influence on posterity, little Greece doubtless won her greatest triumph in the realm of the intellect; for the chisel of Phidias, the brush of Apelles, the logic of Socrates, the speeches of Demosthenes, the tragedies of Æschylus and the inspired verses of Homer have become the legacy and inspiration of the nations. But the preservation, growth and dissemination of these treasures necessitated a perpetual war.

Greece, fighting for Europe and European civilization, met Asia in the longest defensive warfare known in history, and though all the nations constituting the Greek people were no larger than the state of West Virginia, they fought a winning fight with the countless hordes and uncounted treasure of the Persian Empire. From Agamemnon to Alexander, the conflict was felt to be on at every moment of their national life. The "Iliad" of Homer—call it fable or tradition, as you please—reveals the Greeks, a thousand years before our era, waging the Ten Years' War at Troy. Five centuries later the early historical record finds Miltiades victor at Marathon, where Europe worsted Asia and saved the world for progress. Though too early for reliable history, we may safely say that the five centuries between Troy and Marathon could not have been free from Asiatic transgression. Ten years of preparation but repeat the victory of Marathon in the naval fight at Salamis and Europe drives back Asia, Athens wins the leadership of Greece and, uniting the different states in a league against

Persia, founds the so-called Athenian Empire. Revolution and interstate wars were rife, but were all for the one object—the leadership of Greece against Asia. In every war up to the time of Philip of Macedon, Persian gold and Asiatic sympathy had to be reckoned with. Greek unity was never attained and apparently hardly desired, but Greek supremacy was both desired and won. Greece was victor in the seven-century contest, and the gloomy conservatism of Asia yielded to the vitalizing progressiveness of Greece in the policy of Europe; the home triumphed over the harem; hierarchal dictation and monarch's whims gave way to national law on this side of the Ægean; and individual freedom was still possible.

Throughout military history, the volunteer has always fought the most momentous battles, and when the old Greek citizen-soldier drove back Asia he not only saved his people, but fixed the civilization of a continent. Great as was the warrior's service to his race, correspondingly liberal were the honors and awards bestowed by a grateful nation. By special decree of the Athenian Assembly—that national "town-meeting"—the soldier of conspicuous prowess was voted exemption from the financial exactions of state, which not only anticipated the exemption from taxes of estates up to $1,000 of our union soldiers—so patriotically granted by many of our states to-day—but extended further and covered all fiscal contributions imposed by government in either peace or war. Seats of honor at the national theater and great games were awarded; memorial statues were erected; and crowns for bravery, much like the Victoria Cross and Congressional medal of to-day, decorated the heroes of the Grand Army of the Republic of Athens.

And too, that martial state which bore the brave little band of Leonidas and the Spartan mother could hardly fail to do honor to her noble sons who fell fighting for their hearths and shrines. Lycurgus, the Spartan lawgiver, Plutarch tells us, ordered that none but soldiers who lost their lives in battle should have their names, origin and deeds inscribed on their tombs. With green boughs they were laid away and honored with an oration by their fellow-countrymen; but the champions of the host and those Spartan braves who were considered complete warriors were buried in their red coats, with their arms affixed upon their tombs.

How deeply the stern martial virtues of the old Spartan life were engraved on the hearts of her people the mother's treatment of her soldier-boy clearly reveals. It was customary for the Spartan matrons, after an engagement near home, to examine the dead bodies of their sons. Those who received more wounds behind than in front were carried away secretly or left in the common heap; but those who had the greatest number of wounds in their breasts were carried off with joy and triumph to be buried with their ancestors, to whom was offered a worship second only to that paid the gods. The shield was used as a bier on which the dead were carried home from the battle-field and from this custom tradition has handed down the famous appeal of the Spartan mother to her son, on his departure to the conflict, girt with this defensive arm: "Bring it with you or be brought on it," or better still "It or upon it."[1]

Though the Spartans never wrote the history of their wars, fragments of their war-bard, Tyrtæus, singer of the Marseillaise of Greece, seven centuries before our era, ring with tones of Dorian loyalty and scornful pity for the recreant in battle:

Up! Youths of the Spartan nobles,
Ye citizen sons of the elders!
With the left hold out your targes,
And fling your spears with boldness.
Spare not your lives. To spare them
Was never known in Sparta.
—ALLINSON.

How glorious fall the valiant, sword in hand,
In front of battle for their native land!
But oh! what ills await the wretch that yields,
A recreant outcast from his country's fields!
The mother whom he loves shall quit her home,
An aged father at his side shall roam;
His little ones shall weeping with him go,
And a young wife participate his woe;
While scorned and scowled upon by every face
They pine for food and beg from place to place.

. . . .

But we will combat for our father's land
And we will drain the life-blood where we stand
To save our children.
—SYMONDS.

A beautiful custom at Athens by which national gratitude was paid to the memory of her noble sons who fell in battle, was the solemn interment of their ashes in a public tomb in the National Cemetery, situated in the most beautiful portion of the outskirts, near the "Double Gate." This public distinction of the men who freely and deliberately offered up their lives on the field for the freedom and renown of their country and the maintenance of her constitution was considered by the nation a sacred duty not only of gratitude, but of justice. She therefore made provision that the memory of such citizens be fittingly celebrated by orations and perpetuated by monuments. Whether this custom originated at Athens with Solon, the sixth-century lawgiver—as seems very probable—or shortly after the Persian Wars (478 B.C.), it was, beyond question, the most laudable and val-

[1] Plutarch, "Apothegm."

uable, in national influence, of all the excellent customs which the wisest people of antiquity sacredly guarded in its institutions. The tribute paid to the dead by a public acknowledgment of their services; the sympathetic bearing by the body-politic of those losses which burden individual families; the consolation offered by the orator, appointed by the state and speaking to the fathers and mothers, wives and children of the dead soldiers; and the general uplifting of the soul above the sorrows of the mourner to the holy, patriotic joys of the nation's heart, inspired crowds of her citizens with the spirit of deliberate martyrdom and gained for the first republic in the world that heroic devotion that other forms of government can but feebly understand.

The prelude to the splendid funeral oration of Pericles, political master of Athens, gives an interesting description of the ceremonies attending military funerals in the Peloponnesian War (431 B.C.).

> The bones of the dead were laid out under an awning, two days before the funeral,[2] and each man brought to his own relative whatever funeral offering he pleased. On the day of the funeral, coffins of cypress-wood were carried in wagons, one for each tribe—ten in number—and in these were laid the bones of each man, according to the tribe to which he belonged. One empty bier was carried, spread with a cloth, in honor of the missing whose bodies could not be found for burial. Any one who wished, whether citizen or stranger, joined in the procession and the women were present at the funeral to make "lamentation." The remains were then placed in the public tomb which was in the fairest suburb of the city—the Ceramicus—in which they always buried the warriors with the single exception of those who fell at Marathon, and to these, conspicuous for their valor, they gave burial on the very spot. After they had laid them in the ground, a man of high repute and eminent position, chosen by the nation, spoke a fitting eulogy over them. After that the people went home. Thus they buried them and through the whole of the war, on every occasion, they observed the custom.[3]

The oration was repeated on the anniversary of the solemnity and, as Plato said in the Menexenus, "the nation never ceased honoring the dead every year, celebrating in public the rites proper to each and all; and in addition to this, holding gymnastic and equestrian festivals and musical festivals of every sort." Thus did all the different departments of national, religious and artistic life contribute to the glorification of the Memorial Day of the old Athenian volunteer.

A brief analysis of the military panegyric at Athens, together with a few extracts from her most celebrated funeral orations may be of value both as a mirror of the customs of the day and as an expression of the grateful sympathy of the nation's heart. As Bekker has said in his "Demosthenes as Statesman and Orator," "the subject was always the same—praise of the dead soldiers, mourning of their country for her

[2] Private funerals often took place the next day after the decease, cf. Demosthenes, Or. 43, Sec. 62, in a law attributed to Solon. Note similar custom in the gulf states of our country.

[3] Thucydides, Bk. 2, Sec. 34 seq.

loss and consolation for the nearest relatives. It was the duty of the orator, on such occasions, to celebrate the deeds of their ancestors, back to the mythical period and to connect them with the recent glorious achievements of the honored dead. Prescribed usage dictated the nature of the consolation offered—the renown of the departed; the happy lot of the deceased from a consciousness of duty well done on earth; the care the state will take of their families; and finally an appeal to the survivors to submit to their fate and prove themselves worthy of the example set by the fallen heroes. The introduction and conclusion of all the extant funeral speeches are practically alike, beginning with the declaration that the duty imposed on the orator surpasses his strength, which, at the most, can only equal the efforts of previous speakers; and ends with the words 'now go back to your homes after you have bewailed the dead according to custom.'" But after all, it is not hard to justify or difficult to approve the century-tested, ritualistic formality of the old Athenian funeral oration; for a deep feeling of sincere grief must be the dominant note in a funeral speech. Novel thought and fervid rhetoric could bring no comfort to the afflicted, whose hearts, rent with sorrow, respond only to that calm and beautiful language in which the poet has voiced our common and most agonizing woes. A master's task the poet-orator was forced to face!

Of the six funeral orations that have come down to us, two—sometimes assigned to Demosthenes and Lysias—are probably the work of other hands; two others—imaginary speeches but among the greatest specimens of their kind in the world's literature—are the stylistic and patriotic models of Plato in the "Menexenus," and the grand funeral speech Thucydides, the historian, has put into the mouth of the eloquent Pericles; the other two—fragments of funeral orations by Gorgias, the celebrated Sicilian orator and father of rhetoric, and Hypereides, the master-panegyrist of the ancient world—were actually delivered in honor of Athenians who fell in battle.

Pericles closes his celebrated memorial to the dead soldiers, substantially, as follows:

> And it behooves you who survive to pray for a more steadfast purpose and to demand of yourselves that you have no less daring spirit against the enemy than they, considering the advantage of that courage, in no merely rhetorical way but by actually keeping before your eyes the daily increasing power of your country and by becoming lovers in her service; and when she appears to you to be really great, by taking seriously to heart the fact that daring men and men who knew their duty, showing too a sense of pride in their actions, secured this greatness; and when they failed in any attempt they did not for that reason think of depriving their country of their valor but made together the noblest contribution in her behalf.
>
> Sacrificing their lives for the common good, they gained each one their proper meed of never-dying praise and a most illustrious sepulchre—I speak not of that in which their bones lie moldering but of that in which their fame

is enshrined, eternally remembered on every recurring occasion that calls for speech or action. The whole earth is the sepulchre of famous men and not only is the epitaph on the funeral column in their home-land a proof of this, but there abides with all men, even in foreign lands, an unwritten memorial in the heart rather than on the external monument.

Now, from this day, taking these men for your models, judging freedom the only happiness and valor the only freedom, do not neglect the perils of war; for it is not the wretched, despairing of the good things of life, who may more properly be reckless but rather those for whom a change for the worse is the risk they must run while life lasts. They experience the greatest difference if any disaster befall the state. Cowardice and disgrace combined are more painful to a man of spirit than death, insensibly received and attended by courage and hope of the common good.

Wherefore I will not lament with the parents of our dead, who may be present here, but will offer only words of comfort. And they know that they are reared 'midst shifting vicissitudes of fortune. But happiness is gained only when men receive for their lot a most honorable death—as these heroes now—or sorrow like unto your sorrow and their life was finely allotted in the happiness they enjoyed on earth alike with their glorious death.

I know it is difficult to find words that will reach the heart because oftentimes you will be reminded in the happiness of others of those joys in which you yourselves did once exult; and your grief is not for blessings you have never experienced but because you have been deprived of those to which you have become accustomed. But those of you who are still of an age to have children ought to take comfort in the hope of others. The children, yet to be born, will be a private benefit to some in causing them to forget those who no longer live and they will be a double boon to their country in preventing desolation and providing for its security; for it is not fair or just that they should give counsel who may not, by having children too at stake, run the same risks as others. But those of you who are advanced in years may consider so much gain that longer past which you have so fortunately enjoyed and that the remainder of your life will be but short and will rest lightly upon you because of the glory these attained. The love of honor alone never grows old and in the useless period of life getting wealth does not please more, as some say, than being honored.

Before you, their sons and brothers, however many of you there are present here, I see a great contest; for everybody is accustomed to praise those who are no longer with us and you would find it difficult to secure a verdict of equality though you surpassed them in valor, but would be thought a little inferior. For the living suffer from the envy that proceeds from competition but the one who is no longer in the way is honored with a good will, far from all feeling of rivalry.

But if I must make any mention of female virtue to you, who will now be reduced to widowhood, I shall express it all in a brief admonition: your great glory is to be found not wanting in the virtue which belongs to your sex, and great will be her reputation of whom the gossip of men says least either in praise or blame.

I have now spoken, in accordance with the law, what I held appropriate, and by our action our dead have already been honored and their children the nation will henceforth nourish and support at the public expense till they become of age—the substantial crown of glory offered to the dead before us and to the survivors of such contests; for where the greatest prizes are offered for valor, there the citizens are the bravest men. But now let every one indulge his grief in becoming manner and then depart.[4]

Plato, the philosopher, wishing to show by a pattern-speech how the eulogists might, on occasion, express themselves in a more exalted and patriotic manner, makes his old master, Socrates the Wise, repeat, as the mouthpiece of that wonderfully clever woman, Aspasia, the splendid address of which the following is the conclusion:

> To the state we would say: Let her take care of our parents and sons, educating the one in principles of order and worthily cherishing the old age of the other. But we know that she will, of her own accord, take care of them and does not need exhortations from us. These, O children and parents of the dead, are the words which they bid us proclaim to you and which I do proclaim to you with the utmost good will.
>
> And on their behalf, I beseech you, the children, to imitate your fathers and you, parents, to be of good cheer about yourselves; for we will nourish your age and take care of you both publicly and privately in any place in which one of us may meet one of you who are the parents of the dead. And the care which the nation shows, you yourselves know; for she has made provision by law concerning the parents and children of those who die in war, and the highest authority is especially entrusted with the duty of watching over them, above all other citizens, in order to see that there is no wrong done to them.
>
> She herself takes part in the nurture of the children, desiring as far as it is possible, that their orphanhood may not be felt by them; she is a parent to them while they are children and when they arrive at the age of manhood she sends them to their several duties, clothing them in complete armor; she displays to them and recalls to their minds the pursuits of their fathers and puts into their hands the instruments of their father's virtues; for the sake of the omen, she would have them begin and go to rule in the houses of their fathers arrayed in their strength and arms.
>
> And she never ceases honoring the dead every year, celebrating in public the rites which are proper to each and all; and, in addition to this, holding gymnastic and equestrian festivals and musical festivals of every sort. She is to the dead in place of a son and heir, and to their sons in place of a father, and to their parents and elder kindred in the place of a protector, ever and always caring for them. Considering this you ought to bear your calamity the more gently; for thus you will be most endeared to the dead and to the living, and your sorrows will heal and be healed. And now do you and all, having lamented the dead together in the usual manner, go your ways.[5]

The closing words of the beautiful oration, delivered by Hypereides over Leosthenes and his comrades who fell in the Lamian War (322 B.C.), pay due tribute to that orator's matchless merit. Far removed from the artificial grief, so common to the panegyric, there is a genuine, dignified sorrow, in the fragment preserved, which bears the mark of sincere though reticent sympathy, and the most expert of modern critics have found a tenderness and trust in this pagan martyr's patriotic exhortation to the kinsfolk of the dead that verges splendidly near the most touching Christian consolation:

[4] Thucydides, Bk. 2, Sec. 43.

[5] Plato, "Menexenus," 249 C., Jowett trans.

It is hard, perhaps, to comfort those who are in such a sorrow; grief is not laid to rest by speech or by observance; rather is it for the nature of the mourner and the nearness of the lost to determine the boundaries of anguish. Still we must take heart and lighten pain as we may and remember not only the death of the departed but the good name also that they have left behind them. We owe not tears to their fate but rather great praises to their deeds. If they came not to old age among men, they have got the glory that never grows old and have been made blessed perfectly. Those among them who died childless shall have as their inheritors the immortal eulogies of Greece and those of them who have left children behind them have bequeathed a trust of which their country's love will assume the guardianship.

More than this, if to die is to be as though we had never been, then these have passed away from sickness and pain and from all the accidents of the earthly life; or if there is consciousness in the next world and if—as we conjecture—the care of the Divine Power is over it, then it may well be that they who rendered aid to the worship of the gods, in the hour of its imminent desolation, are most precious to that Power's Providence.[6]

Hardly less eloquent were the memorials perpetuated by the sculptor's chisel in handsome marbles and enduring bronze. The matchless, Athenian military relief, raised in the Ceramicus Cemetery to Dexileos, one of the Glorified Five in the dashing cavalry charge in the Corinthian War (394 B.C) still stands, a noble testimonial in marble to the mighty triumph of The Last Battle, with its rearing charger and exultant knight transfixing with his spear the fallen foe. Though this may not be a monument erected by the nation, but the patriotic offering of some friend or admirer, it is valuable for our purpose as one of the few memorials to the individual as distinguished from the triumph of the cause.

But the long and notable list of monuments and trophies to the heroic dead began a century before, soon after Marathon (490 B.C.), with the dedication of the little Doric treasure-house, set up by the Athenians out of the Persian spoils, in the holiest place of Greece, at the oracle of Delphi, "the Center of the Earth," and the point of pilgrimage of thousands, on religious mission bent, from all parts of the ancient world. The remains of this, the noblest memorial of the victory at Marathon, have been found in recent years and the sculptured reliefs of Pentelic marble, safely preserved, with their story of Theseus and Hercules, and the battle of gods and giants—symbolic of the recent contests—reveal a chaste grace that must have given an unique architectural delicacy to the whole structure.

The famous battle-pictures by Micon, in the Portico of Frescoes in the Athenian market-place, painted a quarter of a century later, furnished, however, a livelier idea and glorified most effectively the heroes of this most celebrated battle of history. In one scene, the Athenians charge the trousered Persians; in another, the Persians, in their confusion, rush into the marsh in their flight to their ships; in still

[6] Hypereides in Jebb's "Attic Orators."

another scene, Miltiades and the Persian admirals appear; Cynegirus, brother of the tragic poet, Æschylus, is there also, seizing the prow of the galley to which he held fast until the axe severed his arm and interfered with his determination to capture a whole ship, single handed. Theseus, hero-god, inspires their valor as he rises from out of the earth and the gods and goddesses, above the battle, on the quiet heights of Olympus, look down on the pictured scene—all of which furnished to the oncoming generations a most potent and patriotic reminder of the services and sacrifices of their citizen-soldiers.

But by far the most artistic and celebrated memorial to the achievements of the Athenian, in arms, was the beautiful little Temple of Victory, on the Acropolis, the Holy Hill of Athens. At the Fore-Gate, near the splendid flight of marble stairs—over seventy feet broad—stood, and stands to-day, the patriotic shrine on a mighty bastion twenty-six feet high. This lofty spot was a most appropriate site for a temple of Victory; for from this height the Athenian saw Salamis and Ægina near by and the distant coast of Argolis, the citadel of Corinth, and the mountains of Megara—memories of the glorious past and rosy hopes of future victories.

Other temples, by allegorical sculptures, represented indirectly the great struggle of the Persian wars, but little "Victory" wrote clear its motive in its marble-band, which portrayed the contest of actual Greeks and Persians in the decisive battle of Platæa (479 B.C.). The little Ionic temple of Pentelic marble is only twenty-seven feet long and eighteen feet wide, but its frieze, running around the whole structure in high relief, is eighty-six feet long, and the four fluted columns, at either end, thirteen feet high, are made from single blocks of marble. Within the temple-room was an ancient, wooden image of the goddess, Athena, wingless, with pomegranate and helment in either hand. The breast-high balustrade, about the three precipitous edges of the bastion, was adorned with marble slabs of winged Victories, erecting trophies and sacrificing to their queen, Athena—all clad in those wonderfully transparent robes of marble gauze, which, clinging to the figure or floating across the marble field, have remained the most renowned example of their kind in the history of sculpture.

One of the most unique soldier's monuments in military annals is the serpent-column of bronze which once supported the golden tripod, dedicated by the Greeks, at Delphi, nearly twenty-four centuries ago, in commemoration of the victory of Platæa. Emperor Constantine removed it to his new capital and it still stands in the Hippodrome at Constantinople with the muster-roll of the loyal peoples inscribed upon its coils.

Among the many memorials erected by the Greeks, surely the most characteristically ancient, in religious motive and martial emphasis, is the Soros or funeral mound, raised by the Athenians, at Marathon, as a tomb for their fellow countrymen who fell on the spot in battle. The marble lion, which originally stood guard upon its summit, long ago disappeared but the tumulus itself, thirty feet high and two hundred paces in circumference, was excavated by the Greek government in 1890. Nine feet below the present surface of the surrounding plain was found an artificial floor, 85 feet long and 20 feet wide, upon which rested a layer of ashes, charcoal and human bones. A trench was subsequently discovered which contained the remains of the victims sacrificed to the dead heroes. The black figured vases, found with the bones and ashes of the dead, belong to the period of the Persian Wars, and there is no doubt but that the human remains are those of the one hundred and ninety-two Athenians that Herodotus says (Book 6, Sec. 117) fell at Marathon on the glorious day.

And more than this, the Greek showed his devotion to his citizen-soldier not only in the flush of victory but also when defeat turned the splendid anticipations of the patriot into a "Lost Cause," in which the commonwealth went down to its doom in the train of Philip, King of Macedon. The Sacred Band, at Chæronea (338 B.C.), fell fighting to a man, and they made "Chæronea," forever, the symbol of a struggle for liberty. Here, too, the Athenians raised a tomb to their heroes, glorious in their defeat, and the mound and fragments of the Marble Lion of Chæronea are still to be seen on the road to Thebes. The Greek raised his monument to the glorious deeds performed by the volunteer in arms, and in it did not seem to be aware of death or defeat which are apt to characterize the modern testimonial, but looked beyond and above all those inevitable incidents and reared a memorial of incomparable value to the national cause and a miraculous inspiration to brilliant patriotic endeavor—a symbol not of gloom, but of glory, fame and triumph.

Nor did the spirit of democratic Athens content itself with cheers for the dying and offer but a crust for the living; for at a very early period—at least twenty-five centuries ago—a systematic provision for the disabled veteran soldier of the people was entered upon by Solon and continued in apparently unbroken observance down to the day of Chæronea, when the nation lost her sovereignty, soon to be merged in the world-projects of Alexander the Great. In the sixth century before Christ, Solon had a law passed in the case of the wounded soldier, Thersippus—the first name on a pension-roll in history—by which it was decreed that he and all others thereafter "who were maimed in war should be supported at the pubilc expense."[7]

Even Peisistratus, constitutional tyrant at Athens that he was, subsequently endorsed and followed the precedent set by Solon, in this re-

[7] Plutarch, "Lives," Solon, Chap. 31.

spect, either from motives of pure patriotism or as a concession to the popular will and as a profitable asset for use among those who followed and were to follow him. The people were so in sympathy with the old soldier that the mere mention of military service by a veteran of the wars was thought to have a magic influence with the jury in almost any kind of a case, whatever the issue might be, and this can hardly be cited as an instance of looseness of court-practise in old Greek law; for our American juryman has been known to award a verdict in a contract case to the plaintiff "who guarded our liberties," "risked his life," etc., as Wellman, in his recent "Day in Court,"[8] interestingly cites.

The liberal and complete assistance, above bestowed on the disabled warrior by the little Athenian republic, stands out a conspicuous example of popular gratitude and sacrifice, especially when we realize that Rome, mighty mistress of militarism, granted no pension and offered no financial aid to her veteran soldier or to his family till after her republic came to a close and loyalty to the public weal had yielded to allegiance to an emperor.

The help, originally given in the case of wounded soldiers, was extended to all those infirm in body who were rendered less able to make a living because of their disabilities and were, at the same time, rated on the census-rolls at less than three minæ—fifty-four dollars, but with great purchasing power:[9] If the modes of appointment to both the civic and military pensions were similar—as is now commonly implied and quite generally admitted—we possess interesting data of the way in which the people at Athens kept a patriotic yet prudent hand on the situation at all stages of the administration of state-aid, including the grant to the veteran citizen-soldier. The people themselves might examine every case both on the original allowance and at its renewal each year, so that there was but slight danger of abuse from imposition on the part of the unworthy.

Action could be brought by any citizen before the Boulé or unicameral Senate of the Five Hundred, against any suspect who was liable to an annual examination by the body or the public. Lysias, the celebrated Athenian speech-writer, wrote his famous defense of "The Cripple" (oration 24) for a poor but unabashed pensioner, the slinging and stinging nature of which fits so well the subject on trial that the speech is probably the best example of keen character-study ever produced by an expert, and has, despite its oftentimes ludicrous utterances, a bathos—and a pathos too—that justifies its being adjudged the most typical and may be the best of Lysian achievements. The virtually direct award and renewal of the grant by the people—possible in a limited community, if not practical in a larger nation—with one's

[8] Page 197, edition 1909.

[9] Aristotle, "Resp. Ath.," 49, 4.

neighbors, friends or, may be, rivals, helping the worthy or hindering the worthless, has a democratic flavor that smacks of fair play as well as political thrift and popular control. So far as the ancient authorities at present reveal, the pension to the old Athenian volunteer himself was awarded solely on the basis of disability and financial need—a simple yet satisfactory rule for a small nation where gratitude to the patriot came to mean sacrifice on the part of the people.

The law of the land reflected the humanity and patriotism of the loyal Athenian still further by offering complete support and protection to the fathers and mothers and elder kindred of the dead soldier, as noted in the above quotations from the funeral speeches. This pension, which furnished a substantial consolation to the dying warrior and an incentive and exhortation to those left behind, was put under the immediate supervision of the Archons—the highest authority in the land—who were especially entrusted with the duty of watching over the parents and children of those who died in war that they, above all other citizens, might be free from harm and wrong.

The nation also assumed the guardianship of the sons of veterans together with the daughters of the dead soldiers of the republic of Athens. These orphans were cared for during their minority and were trained and educated at the public expense, and with a completeness of compliance with the best standards of the day that the most progressive military powers of our twentieth century can hardly claim to have surpassed in their patriotic treatment of the survivors of the defenders of their lands and laws.

Although we can not prove the date of this Athenian regulation, Aristotle's censure in his "Politics," of the scheme for support of veterans' children, proposed by the engineer and reformer, Hippodamos, shows that a law like this was already in force at Athens before Pericles's day, the fifth century before Christ. In the same passage[10] the philosopher also claims the existence of similar legislation in other cities (city-states) of Greece. It is now thought quite possible that Hippodamos—who originated the rectangular system of streets in Europe; occupied himself minutely with the improvement of the judicial system at Athens; and possessed a legal mind of such originality as to present the pioneer idea in history of a supreme court of appeals—was not a dilatory mover of a law already in force, Aristotle to the contrary notwithstanding, but suggested new and improved proposals in pension legislation, which, in its old form, had already proved of great civic and patriotic value. The subject most certainly received widespread and intelligent consideration.

Though the offspring of citizens, who fell in the wars of freedom at

[10] Aristotle's "Politics," Bk. II., 8, V., 4, and notes, p. 272, of Susemihl and Hicks's edition.

Athens, was exceedingly numerous and their care no light task in a small nation, she took part in their nurture with a striking delicacy of treatment, "desiring, as far as it was possible," as Plato has said in the Menexenus, "that their orphanhood might not be felt by them," and, in addition to support and education during her youth, the laws bestowed on the veteran's daughter, on her marriage day, a marriage portion or dower which was not only a substantial symbol of parental love and protection, but the very badge of legitimacy in the ancient society.

The sons of veterans were not treated as mere dependent charges of the government but, besides receiving their support from the nation, were taught a trade or trained in business to equip them for the battle of life, and were honored with signal marks of public favor in the gymnasia and especially in the sacred choruses of the great national festivals, in which the proud sons of the most prominent families of the Athenian republic felt it a distinction to appear and participate. And finally, when the veterans' sons, who had been wards of the nation, reached manhood, they were released from state control to take their places as ordinary citizens among their fellow countrymen, but amid scenes and ceremonies which were the most dramatic and inspiring on the religious and patriotic calendar.

No more conspicuous place and surely no more auspicious time could have been selected for this glorification day of the soldier's boy; for he was emancipated from his happy tutelage at the March season of the presentations in the great stone theater of Dionysus, which seated thirty thousand people, when filled, as it was sure to be at this time, when, in addition to the large attendance from the Athenian city and nation, many thousands were drawn from all parts of the Greek-speaking world. Here, at this time, the great tragedies of Æschylus, Sophocles and Euripides, the epoch-making comedies of Aristophanes, and the plays of the other noted dramatists were brought out, just across the way from the temple of the wine-god, with whom the ceremonies always began, and in whose honor and worship drama originated and developed.

Amid such surroundings and in the midst of such a multitude, on the gala day of the year, these orphans were presented, clad in full armor, as a symbol and memento of their fathers' valor and as an exhortation to follow their fathers' example. Just before the tragedy proper began, and after the sacrifice, the bestowing of civic and military crowns on the nation's greatest and bravest, and the sacred deposit of the tribute from the "Athenian Empire"—the safety-fund from the protective league against the Persian King—these youths were introduced to the assembled audience by the herald, who proclaimed with loud voice, what the orator Æschines—Demosthenes's great rival—

regarded as a most glorious and valor-inspiring proclamation, recounting that "the fathers of these youths, like brave and good men, had fallen in their country's battles, wherefore the nation had taken charge of their bringing-up, and now on the verge of manhood, having adorned them with an entire suit of armor, dismissed them under happy auspices to watch over their own affairs, granting them likewise most honorable seats in the theatre."

Though the services rendered by the old Greek volunteer were not only national, but even continental in their influence, their recognition by the most celebrated and artistic memorials of the day, and by pension legislation—which, even in the fragmentary laws and references preserved, suffers little, if at all, by comparison with the finished product of the twentieth century—shows a devotion and sacrifice on the part of the people, unique in their loyalty to the constitution of that first republic in the world, political prototype of the great American republic in nearly everything but size. The people of Athens knew no king but law, and early learned that the stability and very existence of a republic, more than any other form of government, depend on gratitude to the citizen-soldier who defends the constitution, and on the creation and cultivation of a spirit of loving allegiance to and loyal observance of the supremacy and sanctity of the law of the land; and the little republic insisted on that truth and taught her citizens that lesson—which all republics must learn sooner or later—but probably never with more striking or exemplary emphasis than in the oath the youth was required to take at the Temple of Aglauros, when, as citizen and soldier, he swore

> That he would not disgrace his arms nor desert his comrade in battle but would fight for his country's shrines; and leave his fatherland not feebler than he found it but greater and mightier; that he would obey the orders of his commanders; that he would keep the laws, not stand idly by if any one violated or disregarded them, but do his best to maintain them; and that he would honor the shrines of his native land.[11]

[11] Lycurgus, "Leocrates," § 76.

LANGUAGE AND LOGIC

BY DR. CHARLES W. SUPER

ATHENS, O.

WHETHER language is coordinate with thought and merely a phase of it; whether it may be used with a very slight admixture of thought; or whether thought is possible without language, are problems that have engaged the attention of thinkers from the dawn of philosophy. That articulate speech is possible without thought, at least to a limited extent, is evident from the lingual activities of children. They talk almost incessantly during their waking hours either to themselves or to others. That thought precedes speech seems to have been the general belief until comparatively recent times. That this was the view of the writer of Genesis, who probably followed an older, perhaps a much older tradition, is evident from the words "and whatever the man (or Adam) called every living thing, that was the name thereof." The author of this statement clearly believed that the first man was fully endowed with the rational faculty and that speech was merely the utterance of a regulated mental activity. The close connection that was supposed to exist between words and thoughts and their potency in the realm of matter is also shown in the account of creation when the different objects were called into existence by the words of the Lord. Probably few persons of the many millions who have read the first chapter of Genesis have taken note of the naïveté of the record. No living being existed except God; yet he is conceived as uttering his purpose every time he performs a new act of creation. He can therefore have talked only to himself. So we have the oft repeated, "And God said." To what extent our common modes of speech are dominated by the spoken word is evident from such expressions as: "What does the book say?" "What does the law say?" "The newspaper says nothing about it." "He can't tell the difference between black and white." "The heavens are telling." "My conscience tells me." "Money talks" and many more. In one of the South African languages "to think" is expressed by "to talk in one's belly." In this primitive way of looking at the problem the utterance of a thought is taken to be of more importance than its genesis. The Logos doctrine that was so fully elaborated by the later Greek and the earlier Christian philosophers is clearly related to the same underlying conception. "In the beginning was the Logos" are the first words of John's Gospel, by which he means the divine reason. This idea is dwelt upon by Goethe in his Faust. When the hero begins to read he says: "In the beginning was the *Word,*

Here I am balked: who now can help afford?
The Word?—impossible so high to rate it;
And otherwise I must translate it
If by the spirit I am truly taught.

So he tries again.

In the beginning was the *Thought.*
Is it the Thought which works, creates, indeed?

Another attempt leads him to translate:

In the beginning was the *Power.*

Finally he declares:

The spirit aids me: now I see the light!
In the beginning was the *Act,* I write.

Many volumes have been written to explain the meaning of the mysterious word Logos, yet the underlying idea does not seem particularly difficult of comprehension. The abstruse doctrines that have been built upon it are another matter. The writer of the fourth gospel understood it to mean the divine reason that existed before anything visible or tangible was created, and through which "everything was made that was made." It was an effort on the part of the dualistic philosophy to account for the creation, or at least for the orderly arrangement of matter, by a power that dwelt outside of it. As matter could not have produced God, God must have produced matter. In the older Jewish philosophy, so far as their thorough-going belief in the constant interference of the Deity in everything can be called a philosophy, the problem never found a place. It also engaged the attention of the early Greek philosophers. We find the same notion underlying Plato's doctrine of ideas, which is not difficult to comprehend in its main outlines. He evidently means that the concept of things exists in the mind of the self-existent designer before the objects themselves are called into being, just as a man who undertakes to make any *thing* has a plan in mind before he enters upon his work; when it is completed the abstract idea is concretely realized. In like manner, a quality may be conceived abstractly before it is embodied in concrete form. In the Cratylus, Socrates asks whether "our legislator ought not also to know how to put the true natural name of everything into sounds and syllables, and to make and give all names with a view to the ideal name, if he is to be a namer in any true sense." The thought was anterior to the word which expressed it. The mind exists independent of the body; it therefore possesses innate ideas, ideas that had a previous and incorporeal being. The idea of justice, for example, existed before it was embodied or externalized in just acts. The maker of a statue, or of a table, or of a house, had in mind its idea or mental image before he could give it a visible form. The visible is fleeting, the conceptual is abiding. This doctrine was developed in contradistinction to that of

Heraclitus, who taught that all things are in a state of flux, and to that of Protagoras in ethics who maintained that man is the measure of all things. Plato doubtless carried his doctrine to an unwarranted extreme, but that there is much truth in it will hardly be doubted. Neither the mute man nor even the mute child is without ideas. The ability to mould language so that it will fit thought closely is the highest human achievement, but it is not essential to thought. The thought-processes of deaf-mutes are to some extent beyond our grasp, but not wholly out of the range of the constructive imagination. It is well to note, furthermore, that our word *logic* is the direct descendant of Logos. Whatever technical or philosophical definition we may give to logic, there is no doubt that speech and rational thought were closely associated in the minds of the Greeks as the history of the term proves. In their philosophical systems dialectic, discussion, question and answer were so intimately connected and interwoven that they were unable to think of them as separated. People who live in an age of books can only realize with a mental effort conditions when they were non-existent or rare. The poet-philosopher Euripides, who flourished about the middle of the fifth century B.C., is said to have been the first man to collect a library. In the nature of the case it must have consisted at most of only a score or two of manuscripts. Besides, he lived in Athens, the center of culture in the ancient world; elsewhere there were strictly speaking no books at all. Our dictionaries designate what they believe to be correct usage. At any rate, they do much to establish it by setting up a standard to which all educated persons endeavor to conform. In this way a language becomes stereotyped to such an extent that it changes very slowly. But dictionaries in the popular sense are of comparatively recent date. The Greeks always felt justified in using any word or phrase they found in Homer, just as we do with respect to biblical or Shakesperean phraseology. But these authors did not get their vocabulary from books. Later writers, notably Plato among the Greeks and Cicero among the Romans, endowed with the power of genius, may be said to have created a language; it was subsequently imitated with more or less success by all who strove after elegance of diction. But it is doubtful whether they formed a single word in the sense in which a modern scientist may be said to do so. Neither does a man who makes a machine make the materials that enter into it. The influence of these two writers is still vibrant in all philosophical and ethical discussion. The same may be said of Kant, another of the world's great thinkers and one of its original geniuses, since he was not much interested in ancient philosophy and preferred to grapple with the problems he set out to solve without the intervention of predecessors. While we can not tell how thought-processes are carried on without words, that they are so carried on does not admit of doubt.

Facts of a strictly scientific character are furnished by the study of deaf-mutes. In my boyhood I was well acquainted with one of these so-called unfortunates. He was a blacksmith, having learned the trade from his father, and was associated with him in the business. When the father desired him to do anything he addressed him in his natural voice: "Dan, I want you to make a lot of horse-shoe nails"; or he might speak of something that had no connection with the shop as: "To-morrow we will plant corn." This young man had never had any systematic instruction and simply "picked up" his knowledge of English. In order to get some further light on the connexus of speech with thought I addressed a letter of inquiry to superintendent Jones of the Ohio Asylum for the Deaf. I quote from his reply.

I take it your questions refer to the congenitally and totally deaf children. Uneducated deaf-mutes would likely have an inarticulate noise to designate a horse or a cow. Many such children have no such noise at all, but designate them by marks or signs. Educated deaf children under the latest system of teaching speech would have a distinct articulate name for "horse" or "cow," and in fact for all objects, actions, etc.; not so clear however as the hearing person but yet clear enough to be understood. The deaf-mute carries on processes of reasoning just like the hearing person. Speech is not necessary to reasoning, neither is language. To those who are familiar with the uneducated deaf child, it is well known that he is in no wise apparently different from his hearing brother. If nature's touch has not dwarfed or deformed his mental powers, he is alert, active, quick to comprehend, quick to act and responsive to calls upon his attention. His body is vibrant with energy and yields readily to the activities of play and games. He answers the call of his parents to do chores about the house with the same interest and enthusiasm as the other children. He is familiar with the fields, orchards, trees which are near and around his home. He is acquainted with the call of the physician and the visit to the dentist and oculist, and knows the official function of one from the other. Every piece of household furniture he knows and its use. He knows the domestic from the wild animal; the one to pet and the other to flee from. In fact as far as ideas are concerned he has perhaps as clear a conception of the uses of everything around him as the other members of the household. Yet he knows not a name of one. The accepted philosophy up to the close of the sixteenth century and the beginning of the seventeenth declared that the deaf child could not be instructed because he lacked language. This doctrine was upheld by some of the brightest minds that our most enlightened countries of the middle ages and thereafter furnished. It was however discovered that a great many bright deaf people had learned to express themselves in various ways, showing their minds as abounding in good ideas with an understanding of the nature and work of almost every thing with which they came in contact, although they were unable to speak, read or write a single word.

The facts above reported, as well as those that have come under my own observation, partake largely of the mysterious. Speaking for myself, I can not comprehend how it is possible to carry on a process of reasoning wholly without the use of words. Such vagaries as we find in "Alice in Wonderland" are not the product of reason, but rather of the constructive imagination as distinguished from the creative. They are much like the products of the mind in dreaming where it is not under the control of the intellect and the will. I find no difficulty in the comprehension of mathematical formulæ, or in grasping the idea of time and space, or of the persistence of force, or of the indestructibility of matter, apart from the terms in which they are stated; but these are propositions quite beyond the mental reach of the child. The theory that we use words as supports just as a lame man uses crutches until he is healed, breaks down before the fact that children do not need verbal crutches and are able to walk, figuratively speaking, without them. It is probable that every normal child born in a civilized community is endowed by nature with certain hereditary capacities which are then spontaneously developed up to a certain point under the influence of its environment. If the development is to be carried farther, the child's environment must become aggressive and begin a course of training. In fact, what we call culture or civilization is the result of an effort exerted continuously by a small part of the community under pressure of the state upon the whole. There is no doubt that men existed in South Africa as early as in northeast Africa; yet in the former region they never got far enough from the primitive stage to construct a government in the modern sense of the term. When in the course of time this small minority loses its efficiency, the disintegrating forces gain the upper hand and the state falls to pieces. This was the fate of all the pre-christian commonwealths and may be the ultimate fate of all that exists at the present time. The educational agencies of a culture-state are engaged in the endless task of rolling a stone up the hill of progress with more or less success. But as soon as the propelling force is relaxed it will probably begin to roll down. With each generation the work has to be done over again almost from the foundation; in other words, there is a constantly oncoming crop of young savages to be tamed and trained. The reason why the Mesopotamian and the Egyptian kingdoms, the Greek and Roman governments, decayed was that the intelligent minority was overslaughed and eventually destroyed by the atavistic agencies that had at no time ceased their activities. The state had foes within and foes without. It was able to withstand both for centuries, but not for ages. They had simply been kept in check. Heroes, as Carlyle would call them, endowed with varying degrees of efficiency built up states and their successors maintained them. The process was partly spontaneous, partly purposive. In like manner language is a spontaneous growth up to a certain point. It never passes beyond this point unless it becomes the object of mental effort. But even effort is powerless beyond a certain stage. No amount of education can make a great writer, or a great poet, or a great orator, notwithstanding Quintillian's dictum that the orator is made. Neither is any government sufficiently powerful to force a language upon a refractory people, as may be seen in the case of Prussian Poland. I quote further from Superintendent Jones:

The best way of describing the language of the partially educated deaf child is to say that it is mixed. The order of words has always been a bugbear to them. The various verb-forms have given them much labor and worry. They are liable to use one part of speech for another, using nouns, adjectives, adverbs, etc., as verbs. A most striking illustration of that came to my notice a short time ago. One little boy was seen to strike another in the class. His teacher reproved him. His defense was "I whyed him and he wouldn't because me." A teacher had taken her class to see the seventeenth regiment leave for the Philippine Islands. She desired to use the occasion for journal writing and as a language drill. On their return the pupils were to write what they had seen. One boy wrote: "Many men were banding, but I did not see them horn." Evidently he was impressed with the great number of men in the band, but noticed that they were not playing when they passed him. A girl in describing sheep-shearing said: "The farmer washed and nicely the sheep."

The last quotation throws considerable light on one aspect of our vocabulary. It is generally held by philologists that the ultimate elements into which all languages can be resolved consist of two sets of radicles, verbs and nouns, all other parts of speech being derived from these. That our grammatical nomenclature is mainly artificial is not to be doubted. Persons without education are unable to see any difference in the functions of words; often, in fact, these are very indistinct. It is a dictum of Homeric Grammar that all propositions were originally adverbs. In English, as in most other languages, almost any part of speech can be used as a verb. I have heard such expressions as: "I don't want anybody to thee-and-thou me." "No if-ing, if you please." The French have a verb *tutoyer,* meaning, "to address another with thee and thou." "If" is probably the instrumental case of a word expressing doubt. Whether, neither and either are plainly comparatives. It is an utter waste of time to discuss the grammatical classification of words. In Greek and Latin the infinitive of the verb and the dative case of the noun have the same sign. The same statement is true in a modified form of the English, as we may see in such phrases as to me, to town, to go, to walk. "To walk makes me tired," hardly differs from "Walking makes me tired." In German any infinitive can be used as a noun, as also in Greek.

The imperfection of language allows the writer to reveal himself. It is because language displays but a part of this subjective world that there exists an art of writing. James Darmesteter in his "Life of Words" says:

If language were the expression of thought and not a more or less happy attempt at such expression, there would be no art in good phraseology; language would be a natural fact like breathing and the circulation of the blood, or like the association of ideas. But owing to that imperfection, we make an effort to get a grip of our thought in all its turnings, in its inmost folds, and to render it better, and hence arises the work of the writer.

This statement, although true to a limited extent, is applicable only to a small minority of mankind. The overwhelming majority is so much under the sway of tradition and possessed of so few new ideas that their vocabulary is entirely sufficient to afford them utterance. Much more to the point is the following:

> Everywhere as the ultimate end of change we find two intellectual co-existing elements, the one principal, the other accessory. After a long while and by an unconscious path, the mind loses sight of the first, and only considers the second, which either drives out the first or restricts its value. Under cover of the same physiological fact—the word—the mind passes from one idea to another. Now this unconscious process carrying the dominant fact from the principal to the accessory detail is the very law of transformation which obtains in the moral world. The history of religions, of social institutions, of politics, jurisprudence and moral ideas, may be reduced to that slow process which causes the unconscious habits of mind to forget the primary fact, to see the secondary fact alone which is derived from it, and to make of it a primary fact which in its turn will disappear before its insensibly increasing successor.

While the origin of the ultimate constituents of words is rarely discoverable, we can often trace their descendants up to our own time. Typical terms are "derive," "rival," "derivation," "rivulet," and many more that on the surface do not appear to have the most remote connection with one another. The ancient Romans called a stream *rivus.* To draw water from a stream was called *derivare,* the act *derivatio.* *Rivalis* was one who lived on the banks of the same stream. The idea of competition or rivalry is probably latent in the term. The insight we get from other sources into primitive conditions makes it plain that every man's hand was against every other man's. We have by no means outgrown this stage. Thucydides testifies that in his time in some parts of Greece the peasants went to work in their fields with arms in their hands in order to be prepared to fight for what they considered their rights at all times.

The Roman soldiers received no pay for their services while in the field, but the state gave them a small allowance for the purchase of salt, an indispensable but costly article of diet, in many places hard to get. This allowance was called *salarium,* whence our familiar word salary. So likewise *emolumentum* was the money paid for grinding the grain. *Lira* means a "furrow," *lirare* to make a furrow, *deliro* to get out of the furrow, *deliratio* a getting out of the furrow; hence, folly, madness. The connection of these words with *delirium* and *deliramentum* is plain. They were evidently formed when the ancient Romans were an agricultural people. That the conclusion follows from the facts is as clear as the law of deduction can make it. A current German phrase to designate mental aberration is "to be out of one's hut." A word that exhibits this gradual change, or rather, extension of meaning almost under our eyes, as it were, is our familiar term "to ship." The verb came into use at a time when goods were generally transported by water; then it was extended to include conveyance by land likewise. Now it is employed to designate the activities of any common carrier whether by land or water. The original signification has been so completely lost that very few persons who use the word think of it, or notice the incongruity between the term and its primitive meaning.

It is almost certain that a good many words—and there is no way of discovering how large the number—are the spontaneous utterances of persons who can give no reason why one form was chosen rather than some other. To this class belong boom, skedaddle, hoodlum, hooligan, spondulicks and a host more. I recall that several words were current in our neighborhood in Pennsylvania to designate certain persons and acts and were usually referred to their authors. As they never got into print they may have since died out. It is easy to see how, in a primitive state of society, a word uttered by some chief would be taken up by his entourage and eventually become a part of the language of the clan; for although language is developed by society, it does not owe its origin to man's gregarious instinct. Every one knows that children often invent names for things that have no relation to or connection with words used by older persons. The theory that the hypothetical *pithecanthropus* was the progenitor of man is no longer held by any competent anthropologist. If we place the fossil remains discovered by Dubois in the island of Java in this class the argument is not strengthened, the chief objection being its comparatively late date. According to the recent and very careful examinations of Klaatsch and Hauser of all known fossil remains of man there were two primitive types which they designate as the Aurignac and the Neanderthal races. Of these the former stood considerably higher than the latter and unquestionably possessed the faculty of speech. With regard to the latter the evidence is not quite so convincing, but is sufficient to produce a high degree of probability, especially in view of the fact that this race, anatomically considered, bore a striking resemblance to the Australian aborigines; and these display a large measure of linguistic capacity.

Although words are often used eventually in a widely different sense from that which they originally bore, the progress from one meaning to another is not always gradual. The first man who used *ship* to designate transportation by land doubtless did so with a clear knowledge of its original signification; this was only forgotten in the course of time. The man, probably a sailor, who invented the article now considered indispensable by seamstresses named it a "thumb-bell" for evident reasons. The Germans call it a *Fingerhood*. Yet it is safe to say that very few English or Germans now think of the original meaning of the word, though it was clearly evident when it first came into vogue. Shortly after Chinese trade was thrown open to American shipping a vessel was lying in one of the treaty ports. A Yankee sailor who happened to be on shore noticed some natives digging a ditch and carrying away the earth in their blouses. Thinking to teach them a valuable lesson, he provided them with a wheelbarrow and showed them how to use it. Coming to the same workmen some time afterward he saw them carrying the wheelbarrow. They found it less trouble to do so than to learn to use it in the proper manner. We have here a practical illustration of what Lord Bacon had in mind when he said that new ideas are conceived in the old way. Many words experience the same fate. They are used for purposes for which they were not intended originally. The mind expands faster than the vocabulary increases, and it is easier to use the old word with a new meaning than to invent a new one. In this way a great number of new significations are sometimes grafted on a stem that may be called hoary with age. According to de Mortillet who has probably devoted more time to the study of the problem than any one else, man has existed upon the earth not far from 240,000 years. Of these about ten thousand belong to the culture period, and six to the historical. We may greatly reduce the first period and it still remains very long. Primitive man had need of but few words. In the nature of the case his vocabulary would increase very slowly. If not more than one or two words a year were added to it he would enter the historic stage with a relatively large stock. The Hebrew Bible contains less than nine thousand words. A writer says, in the introduction to Worcester's dictionary, that the English language embraces about thirty-eight thousand words. "This includes not only radical words, but all derivatives, except preterites and participles of verbs." The Anglo-Saxon vocabulary is about one third smaller. The Greek language up to the time of Aristotle includes about forty thousand words. Why our modern lexicons are so much more comprehensive is easily explained. The fundamental problem, as it looks to us, that primitive man had to solve was how to designate by the sound of his voice objects that were hushed in perpetual silence. He might imitate, however imperfectly the roar of the tempest, the thunder-clap, the noises made by birds and beasts; but how should he designate the sun, the moon, the stars, the flowers of the field? Did his fancy come to his aid so that he felt like the Psalmist when he speaks of the time when the morning stars sang together and all the sons of God shouted for joy? To this question science has no answer and the answer furnished by the imagination is worthless except as a curiosity. Hence the problem of the origin of language has almost ceased to engage the attention of investigators. Every possible theory has been advanced, but none has gained general assent. It may aptly be said to have been consigned to the limbo of unrealizable possibilities.

THE LANGUAGES OF THE AMERICAN INDIANS

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THE day is past when educated people believed that the Indian languages were only random jargons of a few inarticulate sounds, without grammar or order, and so badly in need of supplementary gestures to make them intelligible that the Indians could not converse in the dark. Still farther have we got beyond the point of speaking of *the* Indian language, as if all tribes used essentially one and the same idiom. Such notions may yet linger among the uncultured, and now and then reflections of them still crop up in books written by authors whose knowledge is not first hand. But the progress of science has been so great in the last half century that the world now looks upon the tongues of the native Americans with newer and sounder ideas.

Probably the most important and most surprising fact about American Indian languages is their enormous number. On the North American continent there were spoken probably 1,000, and possibly even more different languages and dialects. Of South America we know less, but everything points to an equal linguistic variety on that continent. The tremendous total is astounding because the aboriginal population in both continents certainly numbered fewer millions than are to-day found in many single European countries in which only one language prevails. The twenty-five or fifty millions of American Indians possessed as many different languages as the billion or more inhabitants of the old world.

Language and History

To the historian and the ethnologist this linguistic diversity is of the utmost consequence, because it affords him his most important means of classifying the native peoples of America, and ascertaining their connections, their migrations and in part even their origins.

To the student of old-world history and ethnology, philology is also a serviceable handmaid, though to a less degree than in America. This happens, in the first place, because the languages of the eastern hemisphere are, on the whole, each more widely spread; and secondly, because history and archeology carry our knowledge of many peoples of Europe, Asia and Africa back for thousands of years—as compared with the bare four centuries since the discovery of America. History is, therefore, much more able to stand on its own feet in the old world than in the new. Nevertheless, when the historian goes back to origins, he has always been compelled, even in Europe and Asia, to call in the aid of language, and sometimes with the most fruitful results.

Starting, for instance, with our own language, English, the tongues nearest of kin to it are Dutch, German and Scandinavian. Next in closeness of relationship are the various Romance languages, evolved from the decay of ancient Latin—such as French, Italian and Spanish. Still more different, but yet with sufficient similarities to make relationship and ultimate common origin absolutely certain, are Russian and the other Slavic languages, Greek, Armenian, Persian and the various Hindu dialects. The Englishmen who first heard Hindu speech certainly did not suspect that the languages of these dusky people were similar to their own, and that a direct connection or community of origin must at one time have existed between the Englishman and the Hindu. Yet philology has shown such to be a fact, which is now a matter of common knowledge, the entire group of languages spoken from England to India being known as the Indo-European family or Aryan stock.

When a student of Hebrew examines Arabic, it is very quickly evident that the languages have much in common. The speech of the ancient Phœnicians, Syrians and Babylonians, and of the modern Abyssinians, is also similar. This group of languages constitutes what is called the Semitic family. Every dialect within the family possesses obvious similarities to every other Semitic dialect, just as all Aryan languages possess certain words and features among themselves. But no Aryan language has any resemblance to or connection with any Semitic language. It is therefore clear that the ancestors of all the Semitic-speaking nations must have had, at some far distant time, a single common origin, and that at this period they were entirely separate and distinct from the progenitors of the peoples that belong to the Aryan family.

The Turkish language is entirely unconnected with either Aryan or Semitic and belongs to a stock of its own. We know from history that the Turks are recent immigrants in Europe and that they came not very long ago, as the historian reckons, from central Asia. But if the Turkish migrations and invasions had taken place 2,000 years earlier than was the case, we should in all likelihood have had no historical record of the fact, and the historian would erroneously classify the Turks as related to the neighboring Aryan nations—unless he called upon philology to aid him.

It has often been asserted that languages are readily learned and unlearned, and that races put them on and off as a man dons or doffs a garment. But in reality there is probably nothing, not even physical type, that is as permanent as a people's speech.

Thus, even to-day Breton, a pure Celtic speech, maintains itself in

France as the every-day language of the people in the isolated province of Brittany—a sort of philological fossil. It has withstood the influence of 2,000 years of contact, first with Latin, then with Frankish German, at last with French. In the same way, its Welsh sister tongue flourishes in spite of the Anglo-Saxon speech of the remainder of Great Britain. The original inhabitants of Spain were mostly of non-Aryan stock. Celtic, Roman and Gothic invasions have successively swept over them and finally left the language of the country Romance; but the original speech also survives the vicissitudes of thousands of years and is still spoken in the western Pyrenees as Basque. Ancient Egypt was conquered by the Shepherd, the Assyrian, the Persian, the Macedonian and the Roman, but whatever the official speech of the ruling class, the people continued to speak Egyptian. Finally, the Arab came and brought with him a new religion, which entailed the use of the Arabic language. Egypt has finally become Arabic-speaking, but until barely a century ago the Coptic language, the daughter of the ancient Egyptian tongue of 5,000 years ago, was kept alive by the native Christians along the Nile; and even to-day it survives in literature.

While nations, like individuals, can learn and unlearn languages, as a rule they do so only with the utmost reluctance and with infinite slowness. Speech tends to be one of the most persistent and permanent ethnic characters.

Indian Linguistic Families

The seemingly endless Indian idioms are by classification reducible to about 150 groups or families, almost equally divided between North and South America. The first problem of American ethnology, after determining and mapping these families, is to deduce the probable migrations of peoples that can be inferred and the connection which existed between different tribes. The second task is to carry out similar inquiries *within* the bounds of each group or family, and in this way to ascertain the minor or more recent affiliations and movements.

The number of languages is large; the aboriginal population was relatively sparse; the necessary consequence is an unusually small number of people per distinct language. In California, where the linguistic diversity reached its height, there were spoken about 135 idioms belonging to 21 families. The total Indian population was 150,000 or a little less—an average for each dialect of almost exactly 1,000 souls, and only 7,000 for each linguistic family. There is something incongruous in comparing the tongue of a paltry 7,000 uncivilized people with, for instance, the whole group of Aryan languages that are the birthright of hundreds of millions of people of the most important nations. Yet to the ethnologist such comparisons are a necessity, for each group of related languages, whether extending only over a little valley, or spreading from continent to continent, is an ultimate unit in itself, which can not be brought into connection with the other or with any other group. Historically the small family may be as significant as the large, for it represents just as separate an origin.

The Great Uto-Aztekan Stock

Perhaps the best known and most important single tribe in America were the Aztecs, who founded and held the city of Mexico and ruled from there over a large part of the modern republic of that name. Excepting perhaps the Incas of Peru, they were the most powerful nation in the new world at the time of its discovery and conquest. Their

civilization, though for the most part borrowed from other tribes rather than invented, was also of the highest. As to their own origin the Aztecs had certain traditions, according to whose testimony they came from a point in the north, called Aztlan, less than a thousand years ago; in other words, some four or five centuries before the overthrow of their empire by Cortez.

While historians have usually accepted this native tradition, philological evidence renders it very improbable. The Aztec language, more properly called Nahuatl, is the southernmost of a trailing chain of related dialects extending through the length of Mexico and the Great Basin region of the United States. Being at the southernmost extremity of this chain, we have every reason to believe that the Aztecs have moved southward—just as it is natural that the Hindus, who are the easternmost of the Aryans, entered India from the west, and the Celts, who are the westernmost, came into their territories from the east. But if the Aztecs had come from Sonora or adjacent parts of northern Mexico as late as four or five centuries before the discovery, their language should still be very similar to the dialects of those districts. This is not the case. Aztec and the languages of northern Mexico are related, but the relationship is undoubtedly distant. In other words, the Aztecs separated from the Indians of northern Mexico so long ago that their language became considerably changed, and there is every reason for believing that they have maintained a separate existence for very much more than 500 years, just as it is a moral certainty that the ancient people speaking Sanskrit, Greek, Latin and Gothic broke loose from one another more than five centuries before we first hear of any of them. Languages do not change over night. In other words, because Aztec is a member, but a *detached and divergent* member, of the great Uto-Aztekan family, it is necessary to conclude that the Aztecs came from the north indeed, but came at a very ancient period.

Cliff Dwellers and Pueblos

In New Mexico and Arizona there formerly lived the Cliff Dwellers, and have lived in historical times the Pueblo Indians, builders of large villages of stone, and constructors of irrigation ditches and other remains of a monumental character. These relics so far surpass anything else found in the United States that the superiority of the Pueblos over all their neighbors is unquestioned. This superiority has led to their being brought into connection with the Aztecs, as the nearest nation that had risen to a similar proficiency in arts and industries.

The Cliff Dwellers and the Pueblos are, however, known to be practically identical in their arts, implements, architecture and even religion—so far as idols and symbols and other visible remains can make the nature of an ancient religion evident. The two peoples are clearly only ancient and modern strata of one race. If, therefore, the ancient Cliff Dwellers were Aztecs, the Pueblos should still show in their language close kinship with the Aztecs. This is not the case, the Pueblo

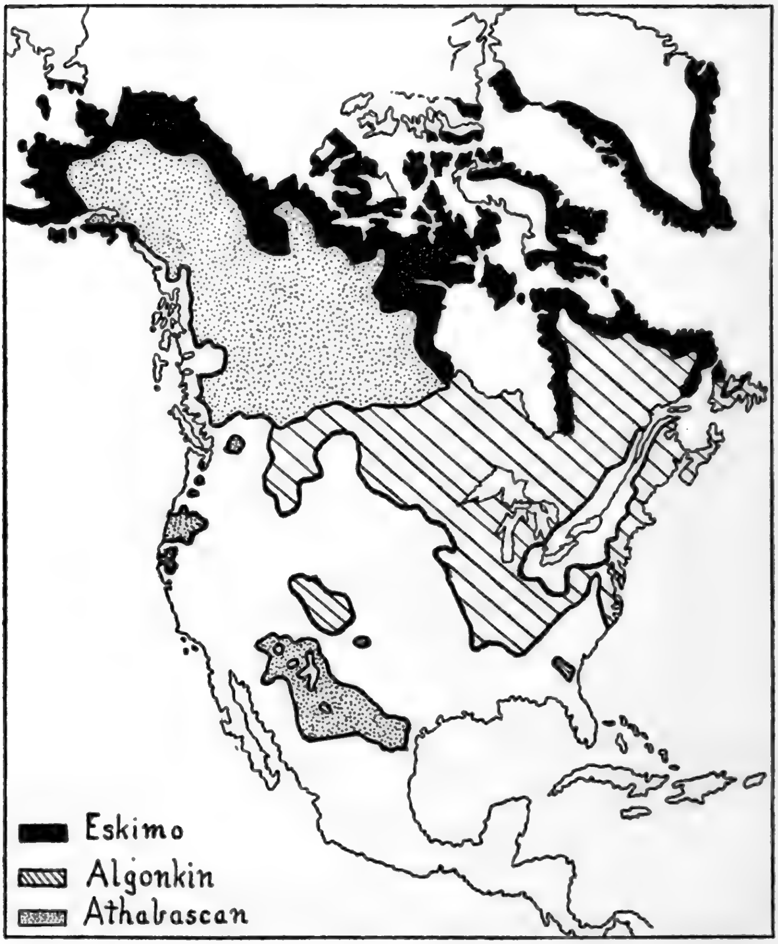
Indians, as a class, not being in any way related in speech to the Uto-Aztekan family. It accordingly follows that the popular identification of Cliff Dwellers and Aztecs is based only on ignorance or imagination, and that the weight of historical evidence is adverse to this view.

The historic development of the great Uto-Aztekan family has been determined still farther. One branch comprises a number of tribes in California. Until recently all these tribes were believed to have been the result of a single immigration into the state. It is now clear that they represent three distinct strata. One mass of them has been resident in southern California for a very long time, long enough for the originally uniform language to divide into several dialects. Another body came at a different time, or by a different route, into the Sierra Nevada Mountains of central California. Whether this movement was earlier or later than the first mentioned we can not yet tell, but it is certain that it was distinct. The third stratum is represented by a recent movement from Nevada westward into the eastern parts of California; but even this was entirely prehistoric.

The Algonkin Family on the Atlantic

Another of the great linguistic families of North America is the Algonkin, one of the first to be known. To this large stock belonged Powhatan, Pocahontas and the other Indians among whom the English settlers of Virginia formed their colonies. Other Indians of the same family formed their treaty with William Penn, sold Manhattan Island to the Dutch, met the Pilgrims from the Mayflower, and learned to read Eliot's bible. Most of eastern Canada, the Ohio Valley, the Great Lake region and the country north to Hudson Bay, were also occupied by Algonkin tribes. Separated from all these, and far to the west of the Mississippi in the great plains at the base of the Rockies, lived three groups of Algonkins that at one time or another had evidently made their way there from the original eastern home. These were the Blackfeet, Arapaho and Cheyenne.

In historic times the Cheyenne and Arapaho have usually been allies and closely associated. They are to-day on the same reservation. But all the inferences made as to a joint migration of the two tribes from their original eastern home have proved mistaken. The Cheyenne language is closely similar to the dialect of the Ojibway and other tribes of the Great Lake region. The Arapaho is more different —so much so, in fact, that when vocabularies of it were first recorded, its essentially Algonkin character was not recognized. It follows that the Arapaho represent an ancient and the Cheyenne a recent separation from the tribes farther east. The third group in the plains, the Blackfeet, have specialized their dialect to about the same extent as the Arapaho, but in different ways. While they, therefore,



branched off at about the same time as the Arapaho, it is clear that they have been distinct from them ever since.

Conservatism of Indian Languages

It has often been said that the languages of Indians and other uncivilized peoples, in fact all languages that are not fixed by writing, change very rapidly. It has been declared that in the course of a generation or two such idioms alter to an extent that men could not understand the talk of their grandfathers, and that in consequence a very few centuries would suffice to alter the features of a language so thoroughly that its original relationship with kindred languages could no longer be ascertained. All such statements are utterly wild, and there is a mass of evidence to contradict them.

Immediately after the Spanish conquest the Aztec language was written down. Documents were recorded in it and extensive grammars and dictionaries prepared. These grammars and dictionaries are perfectly correct and entirely applicable to the Aztec language as it is spoken to-day. The same is true of the various Maya dialects of Yucatan. We possess records going back two centuries and more of Eskimo, Algonkin, Iroquois and other languages of the United States and Canada as well as of South American tongues. In no instance is any notable change observable. It may in fact be doubted whether most Indian languages have changed as much in pronunciation in the last three hundred years as English has since the time of Skakespeare.

Of course the vocabularies recorded some centuries ago and those written down recently are often far from identical, but the principal differences of this sort must be laid to the imperfect and often curious systems of orthography used. Almost all Indian languages contain at least some sounds that do not occur in the languages of Europe. The Spanish conqueror or the French explorer would represent these unfamiliar sounds with different letters than the subsequent English settler or German scientist. In fact differences fully as great as those between old and modern vocabularies can be found in lists of words taken down in the same period in recent times, by different observers, particularly if these observers were of different nationality. It is probable that the superstition as regards the alleged rapid change of Indian languages is due largely to this cause.

The conservatism of American languages is brilliantly illustrated by the Athabascan family, another of the great linguistic stocks of North America. All the Athabascan dialects are remarkably close, so that a person acquainted with one could learn to understand another in a very short time. The same grammatical processes continue through all of them with almost no change. Yet some of the Athabascan tribes occupy the interior of Alaska and the northwestern parts of Canada. Two branches are in the great plains: the Sarsee, closely affiliated with the Blackfeet, and the Kiowa-Apache, almost amalgamated with the Kiowa though retaining their own speech. In New Mexico and Arizona are the Navaho and Apache. In the interior of British Columbia, just south of Puget Sound in Washington, along the coast of Oregon, and in northwestern California, are other areas, each separated from the other, in which Athabascan was spoken. The tribes belonging to the family are scattered over parts of an area measured by more than forty degrees of latitude and sixty of longitude and embracing at least half of North America. Their original center of dispersion is unknown, but wherever they came from in the first place it is clear that it must have taken them a very long time to force their way individually over thousands of miles, over mountains and rivers, and constantly crowding aside hostile tribes as they moved from one residence to a new home. Here again, as in all the historical conclusions which it is possible to draw from linguistic conditions in America, we are dealing with periods measurable at least by thousands of years; and yet in all this long lapse of time the Athabascan dialects have changed but slightly and superficially.

The Eskimo

The Eskimo have often been proclaimed as an Asiatic people. While confined to the shores of Arctic America, their east and west range is tremendous. If one follows the coast, as they must have done in their migrations, the distance between their eastern and western outposts in Greenland and Alaska is at least 5,000 miles. Yet over this whole stretch the language is so uniform that any one dialect is almost entirely intelligible to the people of regions thousands of miles away. The only divergent language belonging to the Eskimo stock is that of the Aleutian Islands. Where the Eskimo came from is still a moot problem, but as there is nothing in Asia to which their language bears any relationship, their Asiatic origin must at best be viewed as doubtful.

How the Languages Sound

Many popular misconceptions are still prevalent as to the nature of Indian languages. It is commonly supposed that they are characterized by strange and harsh sounds such as "clicks" and "gutturals." On examination the so-called clicks turn out to be nothing but a form of l produced more with one side of the tongue than the other and sounding nearly like tl or hl. This sound is perfectly well known in Welsh and in many other languages of the old world. The guttural sounds also are generally not abnormal, and often less conspicuous than in Hebrew and Asiatic languages. As a rule we may state that no native American language possesses any sound formations that can not be exactly paralleled and duplicated in one or more languages of the old world. What is more, it need hardly be said that among a thousand or more languages and dialects there is opportunity for every range of variation, and any attempt to characterize the phonetics of all Indian languages by one term or by a single description must necessarily be fallacious. As a matter of fact there are many forms of native speech that are exceedingly smooth, harmonious and pleasing even to English ears. On the whole the American Indian finds English as full of strange sounds and difficult sound-combinations as we think the Indian languages to be when first we hear them.

Writing of Indian

No American language was written in a native alphabet. So far as the Indians possessed a means of visible communication, it was by picture writing. In the highest development of this, in Mexico, the picture writing took on to a certain degree, but only partially, a phonetic character. Pictures and symbols were sometimes interpreted as such, and at other times read as sounds, almost exactly as in the rebuses with which we amuse idle moments. Even then, however, the characters usually represented whole words, or at best syllables, and as they did not stand for individual sounds they were never true letters, and did not form an alphabet properly speaking.

All Indian philology accordingly rests on an oral learning of the languages, and all writing of them has had to be in systems applied by the investigator from other languages, or specially devised by him. The former was the earlier and less satisfactory method. The Spaniard used the Roman alphabet with its Spanish values, the Englishman and American the letters of English. Where sounds were encountered which are not present in these languages, they were usually either omitted, or represented by a character whose customary value somewhat resembled the sound in question.

More recent studies have generally been based upon a systematic and scientific modification of the Roman alphabet. In this certain principles have now been universally accepted for half a century. The most important of these are three.

First, every character or letter must represent one and only one sound. Second, each sound, whenever it occurs, must be denoted by one and the same character. Third, single sounds must be written by single letters, and *vice versa,* double letters are used only for combinations of sounds. If these principles are strictly adhered to, it does not much matter what characters or modifications of the Roman letters are employed, as long as the investigator is sufficiently conversant with the language not to confuse those sounds which are somewhat similar; and provided also that he furnishes a key or explanation giving the exact phonetic value of every character employed by him. In the choice of characters there are, however, certain preferences. English k and c, for instance, are usually only two different ways of writing the identical sound. In any scientific system of orthography k is preferable because it has the same value in every European language that uses the Roman alphabet, as well as in Greek and the alphabets derived from it. The letter c, however, stands for a great variety of different sounds. In English and French it represents not only the sound of k, but of s, in Spanish th, in German ts, and in Italian, in certain cases, ch. K, which can not be misunderstood, is therefore always used in scientific systems.

In the same way the five vowel characters are pronounced in almost exactly the same way in the great majority of the languages of Europe. Philology, therefore, uses these letters exclusively with their "continental" values rather than with the English sounds, which are quite specialized and which sometimes require two letters, like ee or oo, to represent a single sound, and in other cases express a diphthong or double sound, such as a-i, by the single letter i.

In general very few students of American languages employ precisely the same set of modifications of the Roman alphabet, for the reason that the great majority of them are working with different languages, whose sounds are unlike, so that precisely the same set of diacritical marks would be inappropriate and even inaccurate. The foundation of the system is, however, universally accepted, and may be roughly described as consisting of the vowel characters with their continental values, the consonantal characters with their English values, plus diacritical and typographical modifications to meet particular requirements.

Number of Words

There has been particularly great misapprehension as to what may be called the extent or size of Indian languages—the range of their vocabulary. This is not surprising in view of the fact that similar misstatements are still current as to the number of words actually used by single individuals of civilized communities. It is true that no one, not even the most learned and prolific writer, uses all the words of the English language as they are found in an unabridged dictionary. All of us understand a great many words which we habitually encounter in reading and may even hear frequently spoken, but of which our speech faculties for some reason have not made us master. In short, every language, being the property and product of a community, possesses more words than can ever be used by a single individual, the sum total of whose ideas is necessarily much less than those of the whole body. Added to this are a certain mental sluggishness which restricts most of us to a greater or less degree, and the force of habit. Having spoken a certain word a number of times, our brain becomes accustomed to it and we are apt to employ it to the exclusion of its synonyms.

The degree to which all this affects the speech of the normal man has, however, been greatly exaggerated. Because there are, all told, including technical terms, a hundred thousand or more words given in our dictionaries, and because Shakespeare in all his writings used only fifteen thousand different words, and Milton only six thousand, it has been concluded that the average man, whose range of thought and power of expression is immeasurably below that of Shakespeare and Milton, must use an enormously smaller vocabulary. It has been stated that the average English peasant goes through life without ever using more than six or seven hundred words, that the vocabulary of Italian grand opera is only about three hundred words, and that most of us do well if we know a couple of thousand words. If such were the case it would only be natural that the uncivilized Indian, whose life is so much simpler, and whose knowledge more confined, should be content with an exceedingly small vocabulary.

It is, however, certain that the figures just cited are very erroneous. If any one who considers himself an average person will sit down and make a list or rough estimate of his speaking vocabulary, he will find it to be far above a thousand. It may safely be said that the so-called "average man" knows, and on occasion uses, the names of at least a thousand different things; in other words, that his vocabulary possesses more than a thousand nouns alone. To these must be added the verbs, of which every one employs at least several hundred; adjectives; pronouns; and the other parts of speech, the short and familiar words that are absolutely indispensable to all communication in any language. It may be safely estimated that it is an exceptionally ignorant and stupid person in any civilized country that has not at his command a vocabulary of at least two thousand words, and probably the figure in the normal case is a great deal higher.

When any one has professed to declare on the strength of his observation that a particular Indian language consists of only a few hundred terms, he has displayed chiefly his ignorance. He has either not taken the trouble to exhaust the vocabulary, or has not known how to do so. It is true that the traveler or settler can usually converse with natives to the satisfaction of his own needs with a knowledge of only two or three hundred words. Even the missionary can do a great deal with this stock if it is properly chosen. But of course it does not follow that because the white man in most cases has not learned more of a language, that there is no more. On this point the testimony of the philologist or student, who has made it his business to learn all the language as nearly as may be, is the only evidence that can be considered.

If now we review the Indian languages that have been most thoroughly explored, so to speak, and of which dictionaries are in existence that are even tolerably representative, as of Aztec, Maya, Algonkin, Eskimo, Sioux and several other idioms, it is found that all of these contain 5,000 words, and some considerably exceed this number. What is more, we discover that professions of an *incomplete* knowledge of a language usually come from the very men who have compiled these dictionaries or who have given years to the study of a language. It is the old story that it is only by increased information that one obtains a perception of one's ignorance. The words are there in the Indian languages; it is only when we have learned several thousand that we begin to realize how many there must still be which are unrecorded. It may safely be said that every American Indian language, whether or not it has yet been studied, possessed before coming in contact with white civilization a vocabulary of at least 5,000 different native words.

How the Grammar is Ascertained

Just as the Indian speaks sounds without being able to represent them in writing, and just as he possesses thousands of words without suspecting it, he also follows complex and intricate rules of grammar without being in the least aware of the fact. There is of course nothing strange in this. We are so accustomed to being taught grammar in school that we often allow ourselves to slide into the hasty opinion that we speak and write grammatically on account of this training. There are, however, perfectly illiterate and uneducated people, who, merely through association with those who talk grammatical English, speak with entire correctness. The first grammarians among the Greeks and Hindus did not invent the rules governing speech in their tongues, but only perceived and set down in systematic shape the grammatical forms and constructions already existing in those languages. So it is only a hasty judgment that would conclude that Indian languages are without grammar or form, merely because the Indian does not know that there is such a thing as grammar.

The Indian's ignorance, however, brings it about that the structure of no Indian language can be learned ready made, but has to be gradually explored and worked out step by step. With good interpreters this is a fascinating pursuit, and with proper philological training it is often not as difficult as might at first seem, though it is always a laborious and lengthy task on account of the wealth of the languages and the intricacy of their structure.

For instance, when forms like the following are obtained:

l-emlu-i	I eat
m-emlu-i	you eat
l-emlu-ya	I ate
m-emlu-hi	you will eat
emlu-hi	he will eat

it is obvious on comparing the Indian forms with their English equivalents that the stem *emlu* is the only element that occurs in every one of these Indian words, and the word eat the only one that is common to all the translations. There can, therefore, be no doubt that *emlu* means "to eat." In the same way comparison shows that wherever we have the English pronoun "I," the Indian language in question possesses the prefix *l-*. Similarly "you" is the equivalent of the prefix *m-*, while "he" does not seem to be expressed. A suffix *-i* occurs when the English rendering is in the *present* tense, *-ya* for the *past,* and *-hi* for the English *future.* These five phrases, if we can rely on their having been accurately translated, therefore reveal not only a verb stem, but three pronominal elements and three tense elements. They show, furthermore, that person in the verb is expressed by prefixes, instead of by independent words, as in English, or by endings, as in Latin; and that tense is denoted by suffixes, as in most other languages. In other words, we have derived from these examples a partial idea of that most difficult element in all grammars, the conjugation of the verb.

It is, however, not always as plain sailing as this. The average Indian, even if he has been an official interpreter, has been accustomed to give only the gist or substance of what he has to translate. He has never been troubled with the finer distinctions of tense, mode, number and case, some of which are quite abstract. He is very apt to slur these distinctions over, and to give an approximate instead of an exact translation; so that it is usually necessary to obtain a great number of examples, and patiently compare them, before any positive deductions can be made with safety. In many tribes even the best interpreter's power of expressing himself accurately in English is quite limited, even though he may understand an ordinary conversation perfectly well. If his own language makes no distinction between singular and plural, as not infrequently happens, he uses the English plural and singular indiscriminately. Many Indian languages lack gender and express "he" and "she" by the same pronoun. Most Indians, unless they have gone to school for some time, fail to observe this distinction, and even the school graduate in his unguarded moments is apt to relapse into the habit of calling a woman "he." When "he," "she," "him," "her," "it," "they" and "them" are all expressed by the one general pronoun "him," the investigator has met a serious difficulty.

His only recourse in such an event is to desist from the attempt to obtain exact translations of individual phrases or detached sentences, and to write down from dictation narratives or other continuous texts of some length, subsequently getting these translated as nearly as may be word for word. Even if the translations are inaccurate in detail, they will be enough to give the drift of the story. Then, by knowing the *context*, the student is often able to correct the faulty expression of his interpreter. By the context he will know whether the pronoun refers to a man or a woman, to one person or several, and whether it is in the subjective or objective case. A single narrative or description may be of but little aid, but when a considerable series has been obtained, and has been carefully analyzed, he has in hand sufficient material to determine almost any point, provided he gives it proper time and consideration. It is for this reason that the collecting of texts in Indian languages has been carried on to so great an extent of recent years, and is justly looked upon as a basis of all analysis of Indian languages that pretends to any thoroughness or completeness.

The Phonograph

Great hopes have often been placed in the phonograph, but except as an indirect accessory, the instrument has proved of no service at all to the student of Indian languages, invaluable though it may be for recording aboriginal music. The phonograph still reproduces sound with too great imperfection. When we hear a record in our own language we do not observe this fact, because we are listening for what we can recognize rather than for those parts of the diction which we fail to recognize. Just as we can understand a person who mutters or whispers or speaks with indistinct articulation, simply because we succeed in hearing the majority of the sounds which he utters, and our imagination and familiarity with the language enable us to supply the missing sounds, until we think we have actually heard the whole—so we do in listening to a speech record from the phonograph. We can follow the whole of a record made in our own language, even if it is mechanically only tolerable; but we can hardly write down correctly a single word of a record made in an entirely foreign language. This may seem strange, but can easily be verified by experiment.

The only value of the phonograph to the student of Indian languages is the indirect one of assisting him in the procuring of texts. The Indian informant has every opportunity to speak as naturally and rapidly as he wishes. When a body of such records has been obtained, they can be gone over sentence by sentence, and if need be, word for word, with an interpreter, who speaks as slowly as may be necessary for correct dictation. By this double method the most satisfactory texts can be obtained. Though the labor is increased, and the instrument serves only for the first step of the process, the final product is a perfect written text.

"Gluing Together"

Many attempts have been made to describe briefly and generally the grammatical structure of Indian languages. It has been commonly said that the languages, as a class, are agglutinating, that they "glue" one element to another to form words. But just such pasting together of word elements into words occurs in many of the Aryan languages, in fact in forms of speech all over the world. It is hard to see why on account of some subsidiary difference the same process should be called "inflection" when it takes place in our own language, and "agglutination" when it occurs in Indian or other idioms. It is probably only a desire to set off ourselves from all other people that is at the bottom of the distinction between "inflecting" and "agglutinating" languages.

Polysynthesis

A different description of American languages is contained in the word "polysynthetic," meaning a high degree of combination. There is no question but that many Indian languages are extremely polysynthetic, uniting into a single word, especially in connection with the verb stem, many elements of expression which in English and even in Latin and Greek have to be expressed by a number of separate words. Thus the English sentence "I will roll it there with my foot" would be expressed in the Washo language, from which the preceding illustrations have also been drawn, by a *single* word containing eight syllables, and divisible into six distinct elements.

di-liwi- lup- gic- ue- hi
I- foot-with-roll-thither-will

What is particularly characteristic of the polysynthetic process as exemplified by this word, is that most of the elements as used here can not stand as separate words. They are thus more like our prefixes and suffixes and are more properly word-elements than words in themselves. Thus if the Washo wishes to say "I," as in answer to the question "Who is it?," he says *le;* whereas in composition, as in the above long word, "I" is expressed by the prefix *di-*. The word for "foot" is *mayop,* yet the element or prefix meaning "foot" in a polysynthetic compound shows no relation whatever to *mayop,* being *liwi.* In the same way there or thither as a separate word, as in answer to the question "to where?" is *di;* in a compound word the suffix *-ue* is used.

It is necessary to observe that some American languages do not show this peculiar polysynthetic character, but it is true that the majority of them do possess it, and that some carry it to an extreme degree, so that with references to the languages as a class, it can not be denied that they tend to be polysynthetic.

Every variety of grammatical form can, however, be found in the native languages of America, just as they possess a tremendous diversity of words and of phonetic characters. Some of the languages are very simple, others very complex. Some can be readily learned and analyzed, others present great obstacles. In spite of all the work that has been done by ethnologists, missionaries and others, the great majority of languages are still practically unknown. They offer a tempting and almost unlimited field of philological research. Their study is urgent because many have become extinct and most of the remainder are fast perishing before the inroads of English or Spanish; and it is of the utmost importance on account of the aid which it furnishes to history and archeology. Our future knowledge of the history and prehistory of the American Indian will depend more largely on our knowledge of his languages than on any one other thing.

THE PROGRESS OF SCIENCE

CIRCULATING PROFESSORS

Harvard and Columbia Universities have for several years maintained an exchange of professors with the Prussian government, and both universities have recently made similar arrangements for Paris. Columbia has had at least one visiting professor from Copenhagen, and Wisconsin has recently obtained a Karl Schurz endowment for German professors. Each of our leading universities has lectureships which are frequently filled by foreign men of science and scholars; and there are certain extra university courses, such as the Lowell lectures in Boston and those of the Brooklyn Institute. Thus during the month Professor Svante Arrhenius, of Stockholm, has been giving the Silliman lectures at Yale University; Professor L. T. Hobhouse, of London, lectures at Columbia, and Sir John Murray, of Edinburgh, a course of Lowell lectures. Our students and teachers have for years gone abroad in swarms; foreign students are beginning to frequent our universities, and foreign men of science, scholars and publicists to visit our institutions. Several international congresses have been held in this country and others will follow in due course.

All this exchange of men and ideas has been stimulating and fruitful. Up to the present we have on the whole played the part of the provinces, paying men to come to us and paying for the privilege of visiting them. We have in the main been content to exchange our money for their ideas. With other American republics and with Japan and China conditions have been reversed. With the older European nations they are changing; collectively they still overshadow the United States, but we can compare our institutions and our culture with those of Germany, France or Great Britain on tolerably equal terms.

The official exchange of professors with Berlin has probably been the least successful part of this movement. The visiting professors learn, but their teaching is not particularly profitable. Books and journals are better ways to communicate to one country the scientific work of another, and the foreign language is a bar to oral teaching. A German professor lecturing in his own language for a week in each of twenty American universities would perform a more useful service than in attempting to give regular class-room instruction in one of them. Incidentally it may be noted that attendance at court functions or failure to attend them seems not to cultivate the sense of humor of the American professor.

The eastern seaboard plays somewhat the same part toward the western and southern sections as Europe does to the United States. Students from other parts of the country frequent the eastern universities and their professors lecture elsewhere. But the first official arrangement for an exchange of professors among American institutions has just been announced by Harvard University. A professor is to be sent annually to four colleges in the middle west—Colorado, Grinnell, Knox and Beloit—spending an eighth of a year at each, and the college sends one of its junior officers to Harvard, where he takes part in the regular instruction and may at the same time pursue graduate studies. The scheme is doubtless intended to draw students to Harvard and in a sense usurps the functions of the state university. But it appears to be on the whole commendable. It is certainly desirable for the officers of the smaller and more remote institutions to retain or form associations with the work of the large universities. The professor from the large university may also gain by first-hand knowledge of educational conditions elsewhere. There is, however, a risk that we may by such means cultivate the traits of the propagandist and exploiter rather than those of the scholar. This is the danger to which the American professor is exposed and from which he has not escaped.

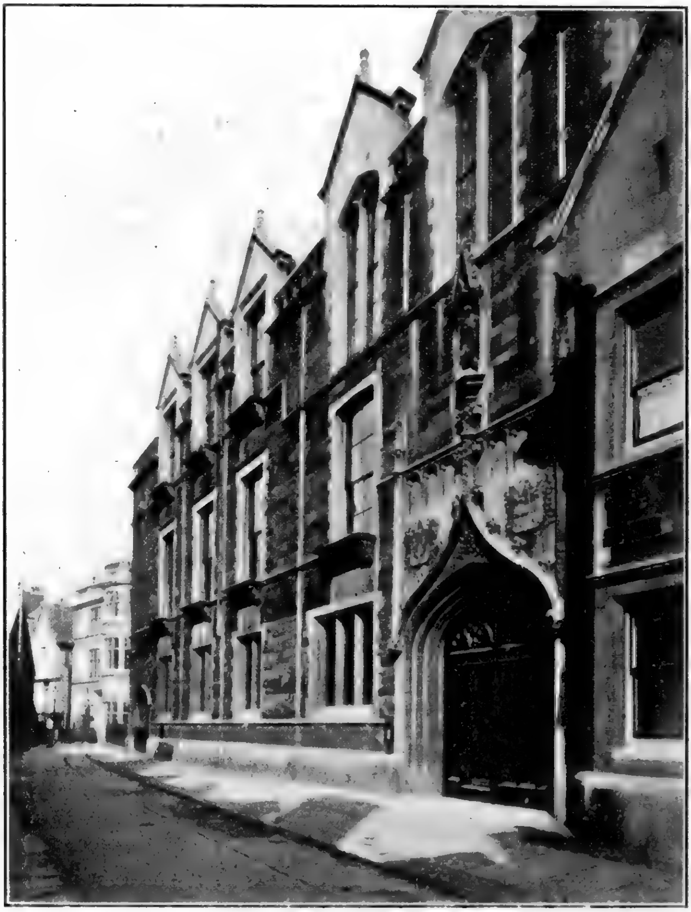
We may hope that the Harvard plan is the initiation of a larger movement which would be wholly beneficial. The colleges of each state should be allied with the state universities or with the private corporations standing in its place. There should be a free exchange of professors and students between all parts of the country. Then there should be a great national university at Washington or elsewhere frequented by advanced students and professors from all parts of the country and all parts of the world—men who would gladly learn and gladly teach. Harvard, Columbia and Chicago, Michigan, Wisconsin and Illinois may be secondary centers, but they should cooperate to establish a super-university, which would have the same relation to existing universities that these should hold to the colleges.

THE CAVENDISH LABORATORY OF CAMBRIDGE UNIVERSITY

CERTAIN centers of research and scholarship are national and international in character. It seems that there would be advantages in greater division of labor, so that one subject or group of subjects would be especially favored at each university. To a certain extent this happens under existing conditions, for a department which is strong is likely to become stronger, while a weak department does not readily improve. But there are usually several universities having departments of about equal strength in a given subject and graduate students find the leading men widely scattered. A large group of students and teachers working in the same field exerts an enormous influence.

A real world center of this character is the mathematical and physical work of Cambridge University, maintained since the time of Newton. The Cavendish Laboratory for experimental physics, established forty years ago, has had in its directors three men of remarkable distinction, Clerk-Maxwell, Lord Rayleigh and Sir J. J. Thomson having in succession filled the Cavendish professorship. At the end of 1909 Sir J. J. Thomson had completed twenty-five years of service and to commemorate a tenure of office so full of achievement his colleagues have prepared a volume giving a history of the Cavendish Laboratory, from which we borrow the facts and the pictures of this note. The book contains a series of chapters in which the Clerk-Maxwell period is reviewed by Professor Schuster, the Rayleigh period by Mr. Glazebrook, and the tenure of Professor Thomson by himself and a number of the former students of his laboratory, including Professor Rutherford. There is given a list of memoirs, containing an account of work done in this laboratory and a list of those who have carried out researches in it. They number more than two hundred, including distinguished investigators in all parts of the world.

The practical teaching of physics and laboratories equipped for research are of comparatively recent origin. At Paris, Oxford and London there were but modest beginnings, when the Duke of Devonshire, then chancellor of the University of Cambridge, gave about $40,000 for the erection of the Cavendish Laboratory completed in 1874. It was enlarged at a cost of $20,000 in 1896, and again in 1908, mainly through the gift of Lord Rayleigh of the greater part of the Nobel prize for physics awarded to him in 1904. According to American standards the investment in the building is modest, but



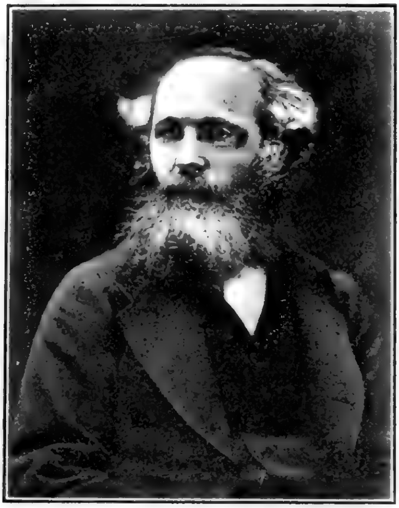
ENTRANCE OF CAVENDISH LABORATORY, SHOWING EXTENSION IN THE DISTANCE.

not so the accomplishment of the men who have directed it and worked in it.

J. Clerk-Maxwell was Cavendish professor of experimental physics from 1871 until his untimely death in 1879. Professor Fleming writes that one of his great courses of lectures on electrodynamics was attended by only one other student, but Hicks, Schuster, Chrystal, Poynting and Glazebrook were among those who worked in the laboratory. Maxwell's investigations on electricity, magnetism and light were in the main theoretical, and their epoch-making importance was fully recognized only after his death; but he exerted great influence on teaching and research in experimental physics.

Lord Rayleigh succeeded Clerk-Maxwell in 1879 and retained the chair until 1884, when he retired to his private Terling Place estate and laboratory. During the period of his professorship he completed his exact measurements of electrical units and other researches of fundamental importance. Regular courses for students were established and women were admitted to the laboratory.

J. J. Thomson, then in his twenty-seventh year, was elected to succeed Lord Rayleigh. He had come to Cam-



James Clerk-Maxwell.

bridge from Owens College and was second wrangler in the mathematical tripos of 1880. Thereafter he began in the Cavendish Laboratory his experimental and mathematical researches, publishing on the electric and magnetic effects produced by the radiation of electrified bodies in 1881 and on the theory of electric discharge in gases in

Lord Rayleigh.
From a painting by Sir George Reid.

1883. Thomson was prepared to assimilate the discoveries of Lenard, Röntgen and Becquerel, and has made the Cavendish Laboratory under his direction the great center for the newer physics and the discoveries of the nature of radiation, electricity and the constitution of matter.

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. Henry Pickering Bowditch, professor of physiology at the Harvard

Sir J. J. Thomson
From a painting by Arthur Hacker.

Medical School for thirty-five years; of Dr. Samuel Franklin Emmons, of the U. S. Geological Survey, eminent for his contributions to the scientific study of ore deposits, and of Mrs. Ellen Henrietta Swallow Richards, instructor in sanitary engineering in the Massachusetts Institute of Technology.

Dr. Theobald Smith, professor of comparative pathology in Harvard University, has been appointed visiting professor at the University of Berlin, for the second half of the academic year 1911–12.—Dr. Edna Carter, instructor in physics at Vassar College, has been awarded the Sarah Berliner research fellowship for women. She will continue her work in physics at Cambridge under Professor J. J. Thomson, and in the laboratory of Professor Wein, of Würzburg, where she received her doctorate.

Dr. C. G. Abbot, director of the Astrophysical Observatory of the Smithsonian Institution, will this summer conduct an expedition to southern Mexico to make measurements of the sun's radiation, which will be compared with simultaneous observations on Mt. Wilson. The congress has made a special appropriation of $5,000 for this work.

The subscription to the memorial to President Grover Cleveland exceeded $100,000 on the seventy-fourth anniversary of his birth. It will be remembered that the memorial is to be a tower forming part of the graduate college of Princeton University.—Mr. James A. Patten has added $50,000 to the $200,000 which he had given to the Northwestern Medical School for the study of tuberculosis.

In the New York senate on March 21 a bill was introduced to incorporate "The Carnegie Corporation of New York." The incorporators named in the bill are Andrew Carnegie, Senator Elihu Root, president of the Carnegie Endowment for International Peace; Dr. Henry S. Pritchett, president of the Carnegie Foundation for the Advancement of Teaching; William H. Frew, president of the board of trustees of the Carnegie Institute of Pittsburgh; Robert S. Woodward, president of the Carnegie Institution of Washington; Charles L. Taylor, president of the Carnegie Hero Fund Commission; Robert A. Franks, president of the Home Trust Company, and James Bertram, Mr. Carnegie's secretary. Under the language of the bill the incorporators are authorized "to receive and maintain a fund and apply the income to promote the advancement and diffusion of knowledge among the people of the United States, by aiding technical schools, institutions of higher learning, libraries, scientific research, hero funds, useful publications, and by such other agencies and means as shall from time to time be found appropriate."

THE POPULAR SCIENCE MONTHLY.

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THE MEASUREMENT OF NATURAL SELECTION

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I. The Status of Darwinism

By organic evolution the broad-minded biologist of to-day understands merely the natural as opposed to the supernatural processes by which the hundreds of thousands of kinds of organisms which now inhabit or have inhabited the surface of the earth have come to possess the morphological and physiological peculiarities which distinguish them from each other. He believes that these differentiable types have been derived by a natural and relatively gradual process from earlier and, in the main, simpler forms.

This belief he shares with all his associates; the evidence in favor of it is considered by scientific men to be so strong that it has become scientific faith and scientific dogma. To-day, only the nature of the processes by which this evolution has proceeded interests biologists. Darwin's theory, and in large measure Darwin's evidence, have accomplished this. At one time Darwinism and organic evolution were synonyms, but now the suffixes "ian" and "ism" and the prefixes "neo" and "ultra" and "post" are combined with half a dozen different names and discussed with a glibness which is bewildering to some of those who are more interested in measuring the intensity of the factors which may have been active in organic evolution than in formulating theories concerning it.

Darwin's theory, viewed from such a distance that trivial details blend into large outlines, involves three propositions:

First, that variations from the typical condition of an existing species do occur.

Second, that these deviations may be inherited.

Third, that in the competition for existence which must result from the inadequacy of space and food for all, certain individuals are by virtue of their characteristics better fitted to survive under their existing conditions of life than others.

For Darwin these were merely hypotheses to be conscientiously tested against all known facts. With the facts which Darwin painstakingly collected and sifted they seemed to agree so well that naturalists accepted his theory as the best explanation of the diversity of the organic world. Fifty years has furnished, it seems to me, a highly satisfactory substantiation of the first two propositions. We have forgotten that it was once necessary to convince biologists that variations do occur, and are now trying to measure the frequency and amount of variations, to determine what their proximate causes are, and to classify them. Variation and heredity are so intimately linked together that one can not be extensively investigated without considering the other. Since the pioneer work of Galton a few men have been actively engaged in the measurement of the intensity of heredity, and of recent years many more have been occupied with the experimental study of the physiological phases commonly known as genetics.

In consequence of this activity our knowledge of variation and inheritance is much more extensive than was that of Darwin—it would be to our shame if this were not true—but if biologists could all escape for a moment from the limitations of vision imposed by the tangle of post-Darwinian detail and by assumption and subsidiary qualification, and could look at the problems and the data of organic evolution as a whole and in the large I think they would be almost unanimous in regarding these two first propositions as so well established that they present no difficulty to the acceptance of the Darwinian theory.

The insecurity of the Darwinian tripod is to be seen in the weakness of the proposition that natural selection moulds the species by eliminating variations not adapted to the environment. While the first two hypotheses have been replaced by the masonry of quantitative science, the third remains largely a hypothesis, weakly reinforced by analogy and by the indirect evidence of adaptation.

To make more widely known the fact that natural selection is capable of quantitative treatment, of direct measurement, just as are variation and inheritance, is the purpose of this essay. It is not a brief for Darwinism, but a plea for direct quantitative researches into one of the more neglected problems of organic evolution.

II. The Problems of Selection

By the word selection in its most general evolutionary sense we mean merely that those individuals which leave offspring are not on the average representative of their generation, but that they differ in some regards from those which do not survive to be parents. In statistical terminology they are not a random sample of the population.

For the evolutionist a question of fundamental importance is this: Do the offspring of selected individuals differ from unselected individuals of the same population? This is, however, really a problem of variation and heredity and not of selection at all. Given variations which are heritable, stringent selection will change the type of the population. If after this change of type no more heritable variations occur, selection can effect no further change.

The history of cultivated varieties shows us that much can be accomplished by selection, but neither the history of animals and plants under domestication nor any amount of experimental evidence would be sufficient to demonstrate the correctness of the third Darwinian proposition.

This has often been recognized. "The real difficulty of Darwin's theory is the transition from artificial to natural selection," said Paul Janet. Darwin himself frankly tells us, "I soon perceived that selection was the keystone of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery to me."

Experimental breeding and statistical studies in variation and heredity can teach us much, but evolution, for the most part, has occurred outside the breeding pen. Some species have originated in the greenhouse and some in a hanging drop culture, but most species have come into existence and biological dynasties risen to dominance and sunk into decadence in the fields and swamps and mountains where organisms live in competition and cooperation, as host and parasite, as destroyer and destroyed. From the standpoint of evolution the vital question concerning selection is: Does selection (natural, sexual or genetic) occur in nature?

Is a selective death rate such an important factor that equipped with proper instruments the biologist can go out into free nature and measure its intensity? If he can, then the Darwinian theory of evolution must detain us longer; if he can not, we must lay Darwinism on one side, and maintain towards it, as towards all other theories for which critical evidence is wanting, an attitude of agnosticism.

III. The Measurement of Selective Elimination

The hypothesis of the existence of the evolutionary factor known as natural selection is dependent upon the assumption that individuals vary in their capacity to withstand the pressure of their environment, and that the differences in resistance to untoward external conditions are associated with and due to differences in the physical, physiological or psychical characteristics of the organism.

It does not assume that every death is selective. Many are due to factors which eliminate irrespective of any particular character; many survivals are due to a fortuitous combination of favorable environmental conditions. Concerning the fate of any individual we can say nothing. The problem is, therefore, a statistical one; evolution, as it occurs in nature, is not a problem of "individuals" but of "populations."

A. *The Protective Value of Color*

For a century field naturalists have observed the close similarity between the colors of organisms and their environment, and have seen in this resemblance an adaptation for protection. Since the advent of the selection theory protective and aggressive resemblance, warning colors, recognition characters and mimicry have been prominent in biological literature, and are conceptions associated with some of the most honored names in biology. Yet almost all the evidence has been comparative, and attempts to determine empirically whether given color patterns are in the long run of vital significance are discouragingly few, and some biologists are now questioning whether the so-called protective adaptations have any value at all.

One of the simplest and most direct tests of the value of any character in determining the chances of survival of an individual is that of Di Cesnola for the protective value of color in *Mantis religiosa.*[1] In Italy the green individuals of this species are found on green grass, the brown ones upon grass burnt by the sun. If the color has any protective value there should be a higher death rate from enemies when the insects are exposed on vegetation of a color unlike their own.

Altogether 110 insects, 45 green and 65 brown were secured and were exposed on separate plants as follows:

Green insects on green plants	20
Green insects on brown plants	25
Brown insects on brown plants	20
Brown insects on green plants	45

The experiment began August 15 and observations were made daily for seventeen days. Of the forty individuals exposed on vegetation of similar color, every one survived throughout the entire experiment. All the green individuals exposed on brown grass were killed in eleven days; of the forty-five brown individuals exposed on green grass, ten survived to September 1, when a severe gale destroyed the experiment. This is all made clear by Fig. 1.

The biometrician would like to see this experiment carried out on a much larger scale, but when we consider that not one of the forty insects exposed on similarly colored vegetation was killed at the end of seventeen days, while sixty of the seventy exposed on dissimilarly colored vegetation were eliminated[2] by the end of the first eleven days, I

[1] Di Cesnola, A. P., "Preliminary Note on the Protective Colour in *Mantis religiosa,*" *Biometrika,* Vol. III., pp. 58–59, 1909.

[2] Most of the insects were destroyed by birds; five were known to have been killed by ants.

think we must regard Di Cesnola's evidence as rather strongly indicating a real protective value in the color dimorphism.

For vertebrates two papers are available. Davenport[3] and Pearl[4] have made observations on the relative number of self-colored and of barred or pencilled birds killed by enemies. Davenport finds that out of 24 chicks from five to eight weeks old killed on one afternoon by three crows only a single one was other than self-colored, although twenty per cent. of the flock of about 300 chicks "had a pencilled or

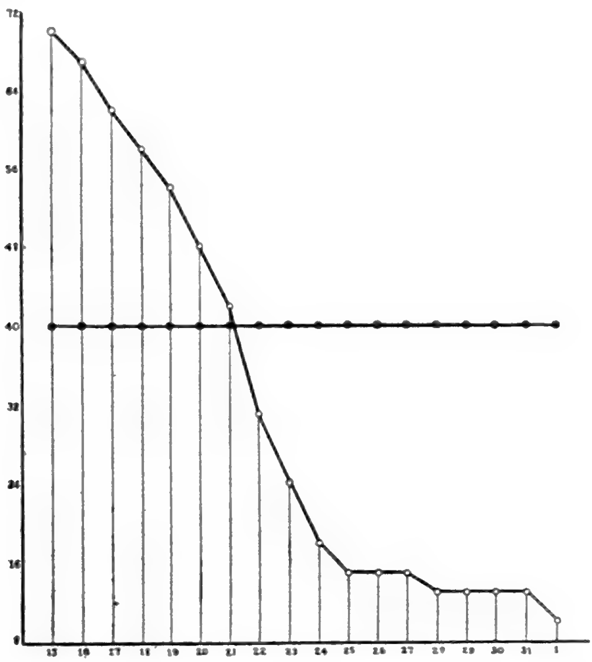


FIG. 1. NUMBER OF INSECTS SURVIVING DAY BY DAY IN SERIES OF BROWN AND GREEN *Mantis* EXPOSED ON BROWN AND GREEN VEGETATION. Ordinates = dates; abscissæ = number of individuals. Similar color in insect and environment represented by heavy dots; dissimilar combinations by circles.

striped marking more or less like that of the female jungle fowl or ordinary game." He concludes, "this fragment, then, so far as it goes, indicates that the self-colors of poultry which have arisen under domestication, tend to be eliminated by the natural enemies of these birds, and the pencilled birds are relatively immune from attacks because relatively inconspicuous."

Photographs by Pearl show that the barred birds are much less conspicuous in their surroundings than are self-colored ones. Theoretically,

[3] Davenport, C. B., "Elimination of Self-coloured Birds," *Nature*, Vol. LXXVIII., p. 101, 1908.

[4] Pearl, R., "Data on the Relative Conspicuousness of Barred and Self-colored Fowls," *Amer. Nat.*, Vol. XLV., pp. 107–117, figs. 1–4, 1911.

their mortality from predaceous enemies ought to be lower, but from a rather large series of observations in his experimental poultry plant only negative results are secured. The actual figures are:

Class of Birds	Number in Original Flock	Eliminated by Known Enemies, Almost all Rats	Eliminated by Unknown Enemies, Chiefly Predaceous Birds	All Eliminated Birds
Self-colored	336	6 =1.79%	29 =8.63%	35 =10.42%
Barred	3007	68 =2.26%	222 =7.38%	290 = 9.64%
Totals	3343	74	251	325

It will be noticed that when the chicks eliminated chiefly by predaceous birds are examined alone, the proportion of self-colored birds is a little higher, but without further statistics no significance could be attached to the difference.[5]

B. *Structural Characters in Relation to Survival*

The comparisons in the preceding section were drawn between well-marked color varieties. Many more experiments of this kind are desirable, but if natural selection be a factor of the potency required to account for the origin of specific characters by the accumulation of small variations, it must be shown that the peculiarities of form or color which separate one individual from another are of significance in determining the ability to more than hold its own in competition with its fellows. So far as I am aware pertinent data are available for structural characters only.

Experiments with Crabs

The pioneer in the measurement of the intensity of natural selection was W. F. R. Weldon. His first attempt to determine whether survival may depend upon definite physical characters was made with the common shore crab, *Carcinus mœnas*.[6]

[5] It would be very interesting if data could be obtained from flocks of young chickens in a diversified environment—*i. e.*, one in which there is a variety of underbrush, weeds, stones, etc., giving wider opportunity for hiding. Davenport's chicks were on a "well-cropped pasture" and Pearl's birds "ran together on the same open, turf-covered range." Now it is quite possible that barring might afford no protection on open turf, and yet be most advantageous in a thicket. Some poultry man could do a very good service to science by appropriating a few hundreds of young birds to the hawks and crows, allowing them to have the run of a lot affording a diversity of shelter. Only where the habitat simulates closely the kind in which animals are found in nature can an experiment of this kind be really critical.

[6] Weldon, W. F. R., "An Attempt to Measure the Death-rate due to the Selective Destruction of *Carcinus mœnas* with Respect to a Particular Character" (Report of the Committee for Conducting Statistical Inquiries into the

Fig. 2 will be recognized at once, even by the reader whose knowledge of marine biology is limited to the menu-fauna of the city restaurant as the outline of the solid upper portion of the crab's body known as the carapace. In measuring the frontal breadth[7] of *Carcinus* from a particular spot of beach near the Marine Biological Laboratory at Plymouth, Weldon and Thompson noticed a peculiar change from year to year. For crabs of the same length of carapace,[8] the frontal breadth seemed to be decreasing.

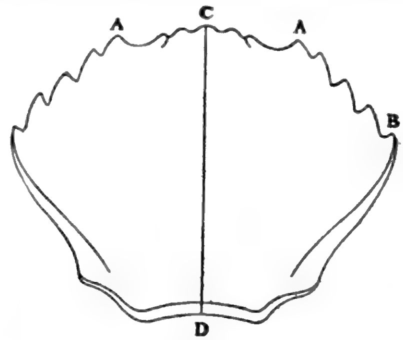


FIG. 2. OUTLINE OF THE UPPER SURFACE OF THE CARAPACE OF THE SHORE CRAB, *Carcinus mœnas.*

I have tried to make this clear by a diagram. In Fig. 3 the individuals are classified into twenty-five groups according to length of carapace and the proportional frontal breadth[9] for each class represented for the three years by the position of the circles.[10] The general slope of the connecting lines convinces one that the Plymouth Sound crabs, as observed by Thompson and Weldon, were undergoing a pronounced change in frontal breadth.

The two reasonable hypotheses to account for this decrease are: (1) A modification of the young individuals by the direct action of a changing environment, (2) a decrease in the average frontal breadth in the population due to elimination of the individuals with broader frontal dimensions.

A change in the environmental conditions of Plymouth Sound was undoubtedly in progress during the time when Professor Weldon's observations were made. The streams bring into the sound large quantities

Measurable Characteristics of Plants and Animals), *Proc. Roy. Soc. Lond.*, Vol. XLVII., pp. 360–379, 1894. Also, W. F. R. Weldon, presidential address to the Section of Zoology, British Association, Report of Bristol Meeting (1898), pp. 887–902, 1899. Interesting and valuable supplementary information concerning Weldon's studies on selective elimination are to be found in Pearson's biographical memoir of Professor Weldon (see *Biometrika*, Vol. V., pp. 1–52, pl. I.–V., 1906).

[7] The distance between the tips of the extra-orbital teeth, from the point *A* to the point *A′* in the figure.

[8] There is no way of knowing precisely how old an individual beast is; if the specimens for different series are sorted into classes of about the same length of carapace, on a line from *C* to *D*, and if there is no reason to suspect any differences due to special environmental influences, dimensions of other parts of the shell can be compared in different lots with reasonable confidence that animals of about the same average age are being examined.

[9] The frontal breadth is expressed in thousandths of the carapace length.

[10] For 1898 the number of observations is not large enough for thoroughly satisfactory determinations.

of fine china clay, while the growing cities along the shore and the shipping have greatly increased the refuse thrown into the harbor. The construction of a huge artificial breakwater has minimized the scour of the tide and the waves of severe storms which formerly swept the fine silt out of the sound, so that this was constantly increasing in amount during the period. These physical changes affected the fauna and some organisms disappeared and were only to be found outside the breakwater.

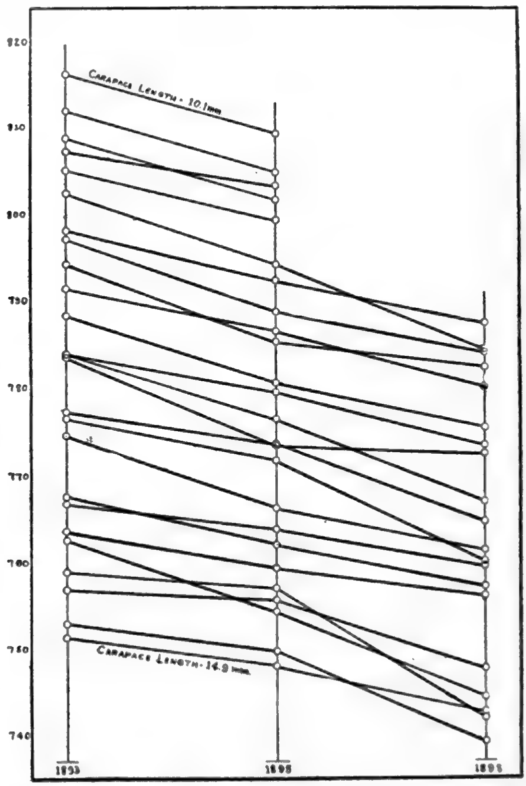


Fig. 3. Change in Frontal Breadth of *Carcinus*. The slope of the lines shows the change in mean relative frontal breadth for crabs of different length of carapace.

As a first series of experiments Weldon put crabs in a large vessel of sea water in which a quantity of fine china clay was kept from settling by a slow automatic agitator. After a period of time both dead and living individuals were measured. In every case the crabs which died were on the whole distinctly broader than those which lived through the experiment, so that a crab's chance for survival could be measured by its frontal breadth. When the experiment was performed with clay coarser than that brought down by the rivers the death rate was smaller, and was not selective.

By washing the stones under which the crabs live along the beach Professor Weldon obtained a silt of a finer texture than the china clay he had been able to use. This was employed in experiments of the same kind, with identical results.

There seems no reason to suppose that the relation of the crabs to the mud on the beach is different from that in the aquarium. Whenever the fine sediment is stirred up a selective elimination of crabs must occur. It is this selective elimination which Weldon regarded as furnishing the explanation of the decrease in frontal breadth observed in the measurements in 1903, 1905 and 1908.

Not content with these experiments, Weldon tried to obtain evidence of an entirely different kind. He arranged several hundred aquaria in each of which a young crab from the beach was kept in clear running sea water—and so entirely free from the influence of the mud. They were allowed to moult and grow and harden new shells. When measured they were found to be unmistakably broader than wild crabs of the same length. This is precisely the result to be expected if a selective elimination of broad-fronted individuals occurs in nature.

The source of this difference in capacity for survival seems to lie in the way in which the crabs filter the water entering their gill chambers. Professor Weldon found that a narrow frontal breadth renders one part of the process of filtration of water more efficient than it is in crabs of greater frontal breadth. The gills of the crabs which died during the experiments were covered with fine white mud, and this was not found in the gills of the survivors.

The labor of these experiments—the daily care of hundreds of animals, the thousands of measurements and the drudgery of calculation—was excessive. Most discouraging of all, perhaps, were the sterile and hostile criticisms which are so often the portion of a pioneer.

Observations on Other Invertebrates.

Results which may be logically attributed to the action of natural selection but which by reason of the possibility of other explanations are not conclusive evidence for its potency, have sometimes been secured by biometricians concerned with other problems. For instance, Warren[11] adduces "the elimination of the physically unfit" as one of the factors to account for the difference in variability of the termites of the same nest at different seasons. Possibly this factor may also account in part for differences in variability from nest to nest, but of course much more extensive and direct evidence must precede any final conclusions.

Another study of variation in insects, social and otherwise, is that

[11] Warren, E., "Some Statistical Observations on Termites, Mainly Based on the Work of the Late Mr. G. D. Haviland," *Biometrika*, Vol. VI., pp. 329–347, 1909.

of Kellogg and Bell.[12] They decide against natural selection, but their evidence for the lady beetle, *Hippodamia convergens,* can not be regarded as conclusive since they have made no direct comparison of eliminated and surviving individuals. Their case for the honey bee where observations are made upon free flying individuals and those which have not yet left the shelter of the hive, is much better, but even here I must feel that their numbers are too small to give finally conclusive results in a problem so difficult as that of natural selection. Furthermore, they suggest that the more abnormal individuals may be made way with before they have the opportunity of leaving the hive.

A most suggestive result was obtained by Schuster in an investigation of deep and shallow water crabs of the genus *Eupagurus.*[13] He finds that for both sexes, but especially for the males,[14] the individuals from deep water were more variable than those from shallow water.[15] Schuster wisely leaves the determination of the reason for this difference in variability to the time when more data, and data collected under the guidance of this first study, shall be available. He points out, however, that if these differences in variability are not those of deep water and shallow water local races, but arise anew in each generation, they must be due either to the direct influence of the environment or to selection. If elimination be the true explanation the less variable shallow-water forms would be regarded as a selection from the more variable deep-water population.

Turning again to studies carried out primarily to test the possible action of natural selection, we may mention the work of Browne on the medusa, *Aurelia aurita.*[16] In this jelly fish the number of marginal sense organs, tentaculocysts, is definitely fixed in the larval stage commonly known as the Ephyra, and by a comparison of collections of Ephyræ and adults it is possible to determine whether variation in the number of the marginal sense organs affects the chance of survival from larval to adult life. Since all of the young and adult populations compared were sensibly identical, one must conclude that neither an increase nor a decrease in the number of tentaculocysts is so injurious that there is any selective elimination during development.

Crampton's study of pupal and pupal-imaginal elimination in the

[12] Kellogg, V. L., and Ruby G. Bell, "Studies of Variation in Insects," *Proc. Wash. Acad. Sci.,* Vol. VI., pp. 203–332, 81 figures, 1904.

[13] Schuster, E. H. J., "Variation in *Eupagurus prideauxi,*" *Biometrika,* Vol. II., pp. 191–210, 1903.

[14] Deep water forms were those taken at a depth more than 35 meters; shallow water forms from a depth of less than 35 meters.

[15] The males are more variable than the females, in both deep and shallow water.

[16] Browne, E. T., "Variation in *Aurelia aurita,*" *Biometrika,* Vol. I., pp. 90–108, 1901.

Ailanthus silk-worm moth[17] I will pass by without discussion, since I believe he is soon to publish further observations on the same subject.

Weldon's work on natural selection was not limited to crustacea, but extended to the mollusca as well.

The shells of certain snails, such as *Clausilia* and *Helix,* is essentially a tube increasing in size as the animal grows older and wound in a spiral, or more properly a helix, around a central axis with the successive coils in contact. If one of these shells be cut longitudinally, the central cone, or columella, as it is technically called, will be laid open and will appear as a narrow conical tube extending the whole length of the shell, while the tube which contained the animal will be cut across twice in each complete revolution and will appear in cross section.

This point is made quite clear by an examination of the three diagrams (Fig. 4).

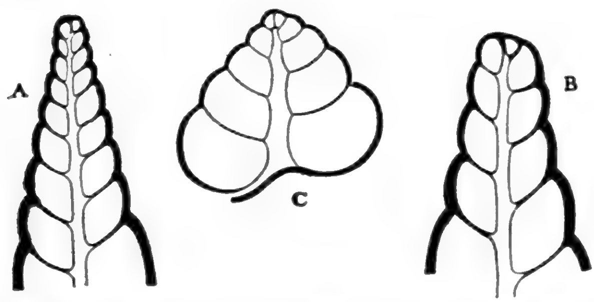


FIG. 4. LONGITUDINAL SECTIONS OF *Clausilia laminata* (*A*), *Clausilia italia* (*B*), and *Helix arbustorum* (*C*), after Weldon and Di Cesnola in *Biometrika*.

By deft manipulation such sections can be prepared. A shell may be ground upon a soft stone until a plane which extends almost exactly through the central columella is exposed.[18] From such a preparation it is quite possible to make the measurements which determine the pitch and several other characteristics of the spiral.

The shell of these snails is a permanent structure. In the adult the whorls first laid down by the young animals can be measured. Now it is clear that one can compare the properties of the portions of the spiral already laid down in the shell of a young snail with the same portions in the shell of an adult. In snails, as in other animals, not all individuals survive to adult life. The problem is to find out whether the properties of the first-formed portions of the spirals of the shells of

[17] Crampton, H. E., "Experimental and Statistical Studies upon Lepidoptera. I. Variation and Elimination in *Phylosamia cynthia,*" *Biometrika,* Vol. III., pp. 113–130, 1904.

[18] To be sure, the work is exceedingly tedious and many shells are accidentally spoiled, but four or five may be prepared in a day's work and in the course of time a number sufficient for statistical work may be secured.

individuals which have survived to adult life differ from those portions of the shells of young snails, part of which will survive and part be eliminated. If differences do occur they are most easily explained as due to a selective mortality in the animals during their period of growth.

Details of measurement and calculation are entirely too elaborate and complicated for explanation here. In two studies, one by Weldon[19] on *Clausilia laminata* from Gremsmühlen in Holstein and one by Di Cesnola[20] on *Helix arbustorum* from the banks of the Isis near Oxford, the authors found that while there is no difference between the mean characters of young and old shells there is a distinct difference in variability. This kind of selective elimination which recurs every generation and by which the existing type is maintained (without necessarily giving rise to any progressive change) Weldon designates as periodic, in accordance with Pearson's terminology.[21]

The reader must not conclude from what has just been said that Weldon regarded variation in the peripheral radii as the direct cause of the selective elimination. "Such selection is, of course, 'indirect,' that is to say, the life or death of the individual is determined in each case by the value of a (probably large) number of correlated characters, of which the length of the peripheral radius is only one." With justice Weldon emphasizes the minuteness of the structural differences which seem to mark the boundary between fitness and unfitness for survival in *Clausilia laminata.*

The results of Weldon's investigation[22] of *Clausilia italia* did not agree with that of his former study of *C. laminata*. By some readers this fact will be interpreted as vitiating entirely any conclusion to be drawn from all this laborious work on shells. To my mind this attitude is quite wrong. Laying aside the fact that Weldon has suggested biological reasons which may explain why no change in variability was observed between young and old individuals in *C. italia,* we must bear in mind the fact that there is no justification whatever for assuming that natural selection, either secular or periodic, is to be observed at all times in all species. Naturally contradictory results call for repetition and amplification and for more refined control of conditions—but these are the things which make for the advancement of science. Only the merest beginning has been made in the study of selective elimination, but Weldon has shown us the way in which the problem may be attacked in two large groups of invertebrates. If other workers with his patience are ready to volunteer their service to this phase of evolution,

[19] Weldon, W. F. R., "A First Study of Natural Selection in *Clausilia laminata,*" *Biometrika,* Vol. I., pp. 109–124, 1901.

[20] Di Cesnola, A. P., "A First Study of Natural Selection in *Helix arbustorum,*" *Biometrika,* Vol. V., pp. 387–399, 1907.

[21] Pearson, K., "Grammar of Science," 2d ed., pp. 412–414, 1900.

[22] Weldon, W. F. R., "Note on a Race of *Clausilia Italia,*" *Biometrika,* Vol. III., pp. 299–307, 1904.

the next ten years ought to see a material advance in our knowledge of the least investigated of the Darwinian principles.

Studies of Vertebrates.

The relative ease with which large numbers of individuals can be secured and observed is an ample explanation of the fact that practically all the studies of selective elimination have been made on invertebrates.

To Dr. H. C. Bumpus belongs the credit of the first effort to determine whether the death rate among vertebrates may depend in some degree upon the measurable physical characteristics of the individual. Indeed, in the attempt to apply quantitative methods to the problem of natural selection Bumpus[23] was a close competitor for priority with Professor Weldon. His statement of the problem, like that of Professor Weldon, is beautifully clear:

> A possible instance of the operation of natural selection, through the process of elimination of the unfit, was brought to our notice on February 1 of the present year (1898), when, after an uncommonly severe storm of snow, rain and sleet, a number of English sparrows were brought to the anatomical laboratory of Brown University. Seventy-two of these birds revived; sixty-four perished; and it is the purpose of this lecture to show that the birds which perished, perished not through accident, but because they were physically disqualified, and that the birds which survived, survived because they possessed certain physical characters. These characters enabled them to withstand the intensity of this particular phase of selective elimination, and distinguish them from their more unfortunate companions.

From his measurements of various bodily dimensions Professor Bumpus concluded that the birds which perished were actually differentiated from those which survived. Some of the differences, however, are so small that to the cautious statistician this attempt to measure the influence of a selective death rate on the type of a population of birds living in a state of nature seems suggestive rather than finally conclusive.

This must not be read as a criticism of Bumpus's work, for he not only saw the problem and the possibility of applying the new methods to it, but he also gave us the full results from an unusual opportunity.

First and last, considerable has been written concerning natural selection in man. Most of the arguments are purely general or specu-

[23] Bumpus, H. C., "The Elimination of the Unfit as Illustrated by the Introduced Sparrow, *Passer domesticus*," Biological Lectures from the Marine Biological Laboratory, Woods Hole, 1908, pp. 209–226, Boston, 1899. For further statistical constants calculated from Bumpus's data see a note entitled, "A Neglected Paper on Natural Selection in the English Sparrow," *Amer. Nat.*, May, 1911, p. 314–318.

lative, but Beeton and Pearson[24] have succeeded in obtaining more definite evidence.

From extensive researches on inheritance in man, Pearson and his associates have shown that duration of life gives much lower correlations—both parental and fraternal—than the substantial values found for other physical and psychical characters. If the duration of life of an individual were absolutely determined by physical and mental fitness, then one would expect it to show a correlation as high as that found for other characters. The fact that the values are regularly and conspicuously lower evidences for the existence of a non-selective death rate. The relative amount of the selective and non-selective death rate may be roughly estimated from the reduction in correlation as one passes from the inheritance of characters in general to that of longevity. By this means Beeton and Pearson calculated that from fifty to eighty per cent. of the death rate in civilized man is selective.

C. *The Fitness of Organs*

Except among the lowest forms of life, every animal or plant is made up of a large number of parts which are differentiated in form and function. The fitness of such a complex organism for self preservation and perpetuation probably depends not merely upon the degree of development of its several component members, but also upon the nicety with which they are coordinated.

Undoubtedly the proper way of taking up the study of Natural Selection is to compare by means of the measurement of particular organs series of individuals which survive with series which perish, but after this is done in a large number of cases we shall have considered only the first part of our problem.

This first phase consists in finding out whether variations in the form, size or other property of an organ affects its efficiency to such an extent as to prejudice the chances of survival of the individual possessing it.[25]

Involving, as it does, questions of structural characteristics and functional efficiency this is at bottom a problem on the boundary line between morphology and physiology. For several years it has seemed tc me that we might, in the long run, make better progress in the study of the problems of evolution if we turned our backs on some of its more

[24] Beeton, Mary, and K. Pearson, "A First Study of the Inheritance of Longevity and the Selective Death-rate in Man," *Proc. Roy. Soc. Lond.*, Vol. LXV., pp. 290–305, 1889. Beeton, Mary, and K. Pearson, "On the Inheritance of the Duration of Life, and on the Intensity of Natural Selection in Man," *Biometrika*, Vol. I., pp. 50–89, 1901.

[25] In actual work one is at once confronted by the difficulty that variations in the organ he is studying may have no real influence upon the chances of survival but merely an apparent significance due to its correlation with other organs.

complex phases and devoted ourselves temporarily to the morphological and physiological problems upon which they rest.

While testing out this idea in studies of the relationship between structural characteristics and fertility in various fruits, certain inconsistencies in results were found which could be most easily explained by the assumption that there is a selective elimination in which ovaries

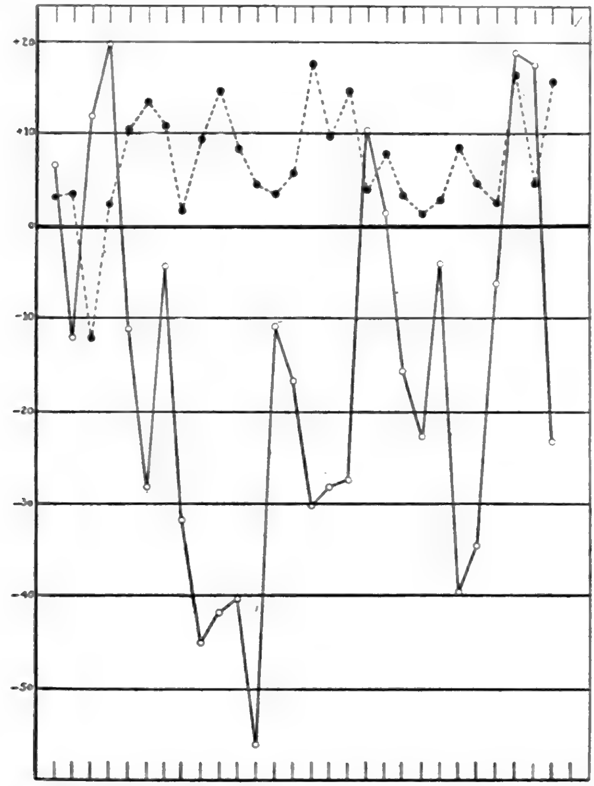


FIG. 5. COMPARISON OF MATURED FRUITS WITH FALLEN OVARIES FOR TWENTY-EIGHT INDIVIDUAL SHRUBS OF *Staphylea*. Differences expressed in percentages of the mean of the eliminated series. Solid dots and broken lines = mean number of ovules; circles and firm lines = radial asymmetry.

of certain types are extensively weeded out. Direct investigation proved the correctness of this assumption. The results will be set forth very briefly.[20]

In the selective elimination which occurs during the development of the ovary of the American bladder nut, *Staphylea,* into a fruit, the

[20] Those who care for a detailed account may find it in three papers: (*a*) "Is there a Selective Elimination in the Fruiting of the Leguminosæ?" *Amer. Nat.*, Vol. XLIII., pp. 556–559, 1909; (*b*) "On the Selective Elimination during the Development of the Fruits of *Staphylea*," *Biometrika*, Vol. VII., pp. 452–504, 1910; (*c*) "On the Selective Elimination of Organs," *Science*, n. s., Vol. XXXII., pp. 519–528, 1910.

mean number of ovules is materially increased. For a small series of developing ovaries taken at the Missouri Botanical Garden in 1906, the oldest—the group from which the most elimination had taken place—had about eight per cent. more ovules per fruit than the youngest. In large samples taken in 1908, the fruits which matured had about seven per cent. more ovules than those which were eliminated. The same result is seen if the material is split up into twenty-eight individual pairs of samples, each from a separate tree. This is made clear by Fig. 5. The solid dots connected by broken lines show the percentage excess of the matured fruits over the fallen ovaries in the number of ovules. In twenty-seven cases out of twenty-eight the number is larger in the ovaries which mature!

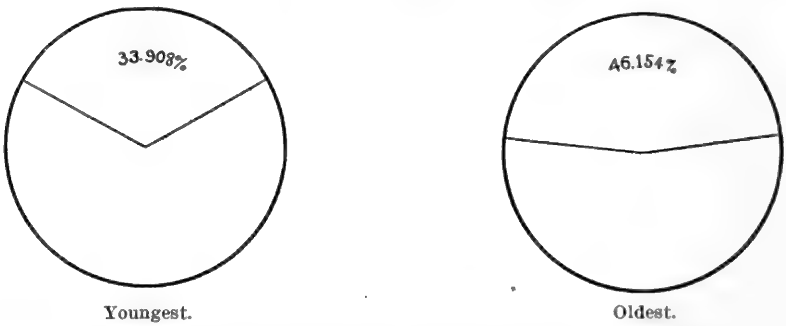


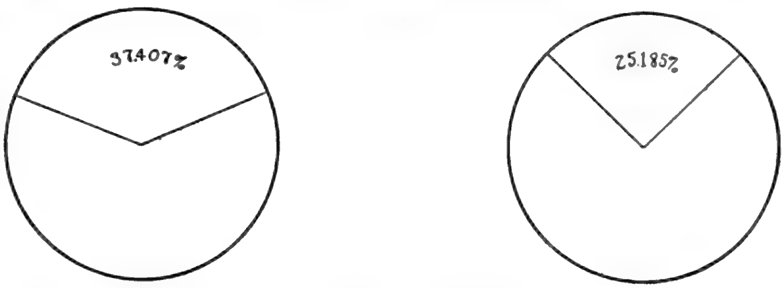
FIG. 6. PERCENTAGE OF OVARIES WHICH ARE PERFECTLY RADIALLY SYMMETRICAL IN YOUNGEST AND OLDEST COLLECTIONS, Missouri Botanical Garden, 1906.

The ovary of *Staphylea* is three-celled. If each cell contains the same number of ovules, *e. g.*, 8–8–8, it may be regarded as radially symmetrical, while if the numbers differ from locule to locule, for instance 8–7–8 or 9–10–8, the ovary may be described as radially asymmetrical. If this radial asymmetry be expressed by a statistical constant such that a perfectly symmetrical fruit shall have a degree of asymmetry of 0, while the coefficient increases as the ovaries become more irregular, one can compare asymmetries in the ovaries which do and those which do not develop to maturity as easily as he can the means.

Fig. 6 shows the percentage of perfectly symmetrical ovaries in the youngest and oldest series of the 1906 collection. The conclusion that the conspicuously higher percentage of perfectly symmetrical ovaries in the oldest collection is due to a selective mortality by which the more irregular ones are weeded out is fully substantiated by the statistics of 1908.

The average asymmetry for the matured fruits for 1908 is about seventeen per cent. lower than the mean for the eliminated sample. For the individual trees the results are somewhat more irregular than they were for the mean number of ovules, but Fig. 5 shows that in twenty-one cases to seven the asymmetry of matured fruits is less than that of the ovaries which do not complete their development. Taken as a whole, the differences show an unmistakable tendency to fall far to the negative side of the 0 bar.

Not merely the degree of radial asymmetry of the ovary, but the number of its locules which have an odd number of ovules, seems to be of consequence in determining whether an ovary shall complete its development. Ovaries with even numbers—6, 8, 10, 12—of ovules in their locules have a better chance of developing to maturity than do those with one or more locules with an odd number. The question is too involved for adequate discussion, and I will leave the subject with a mere reference to Fig. 7 which shows that in the 1908 series the reduction in the percentage of "odd" locules is a very material one.



Eliminated. Matured.

FIG. 7. PERCENTAGE OF "ODD" LOCULES IN ELIMINATED AND MATURED OVARIES OF *Staphylea*—1908 collection.

The work just outlined has been rather drastically criticized on the ground that studies on the selective elimination of organs can never have any bearing on the problem of evolution. I think there is room for differences of opinion on this point, but at present the purely morphogenetic and physiological sides of the problem are of paramount interest; our knowledge of facts is too meager to justify speculations on so complex a problem as that of the origin of species.

IV. CONCLUDING REMARKS

In the paragraphs which have preceded these I have tried to set forth honestly the results which have been secured in attempts to ascertain by direct quantitative methods the intensity of the selective elimination which may occur in nature.

What is the general significance of these results? What claim have they to the special attention of scientific men?

First, let us premise that *the measurement of natural selection* is not synonymous with such an expression as *the demonstration of the natural selection theory.* Upon the application of biometric methods many supposedly valid biological theories have shrunken to nothing;

possibly this may ultimately be the fate of the natural-selection theory. In approaching the problem our aim is not to "get positive results," but to find out the truth. Our object is not to bolster up a venerable and out-of-fashion hypothesis, but to test conscientiously that hypothesis against concrete data.

Like other theories, the Darwinian theory must stand or fall according as the evidence of quantitative biology shall be for or against it. If the micrometer scale and the calculating machine show that any given character has no influence in determining whether an individual shall survive, then for that organ, in that species at the time under consideration, evidence for the potency of selection is wanting.

The problem is a difficult one; *a priori* one would expect most generally to find no changes taking place in the characters of a species because of a selective death rate. If natural selection be actually at work in nature, it is likely that the ancestors of individuals collected in the open will have been subjected to the selective factors which one is trying to measure, and that the race will be held pretty close to the attainable limit of perfection. It is more likely that a selective elimination which recurs every generation will be observed than one of the kind that brings about changes in specific characters. Only in rare cases when a new territory is opened to organisms or some special modification of environment (inorganic or organic) has taken place can we reasonably expect to see the changing of types going forward. Possibly the very difficulties of demonstrating a selective death rate bear witness to its reality!

Taking all this for granted, biologists must, it seems to me, face the duty of determining whether natural selection is a fundamental factor in evolution—in short of actually measuring the intensity of the selective death rate. The calipers are ready and their efficiency has been proved.

The duty to use them is imposed by ideals of good workmanship. "Measure that which is measurable and render measurable that which is not," is the ideal which has hitherto separated the precise from the descriptive sciences. It is the duty as well as the opportunity of the biologist of to-day to break down this distinction.

The duty to use them is imposed by the history of our science. For nearly half a century natural selection has been one of the chief problems of biology, and it would be cowardly for naturalists of this generation to leave the problem until a definite solution has been secured.

The duty to use them is imposed by the inability of the biologist to construct for himself a philosophical theory of evolution without natural selection as one of the factors. Yet the philosophical necessity of a given factor does not relieve the scientist from the duty of finding out whether that factor be a reality, and of measuring its intensity.

THE RELATION OF BIOLOGY TO AGRICULTURE

By Professor F. R. MARSHALL
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UNTIL a few months ago Americans were inclined to express surprise at the paternalistic measures for fostering agriculture as adopted by other countries. Now, the necessity of ensuring adequate food supplies has made us willing to assume the same encouraging attitude toward agriculture as we have always held toward our manufacturing enterprises.

Last year we seemed broad-minded and liberal in what we were doing for the promotion of agriculture, and our motives were really largely philanthropic. We knew that the bulk of our population fared more sumptuously, if not more wisely, than the inhabitants of other nations, but it was maintained that the American laborer was the superior of the European, and his standard of living was, and must continue to be, a higher one. Now we would foster agriculture because we see our dependence upon that industry. The disposition to foster agriculture is evidenced by such actions as the legislatures' requesting the agricultural colleges to establish correspondence courses.

Although the meat boycott was heard of only in its organization, even that move showed plainly that either the standard of living or our agriculture must change. Doubtless both will be greatly modified.

It is not necessary to argue the urgent and immediate need of a more intelligent and scientific agriculture. Present prices are already inciting greater study, as well as adding to the numbers of farmers. The apparently diseased condition over which we have temporarily disturbed ourselves really exhibits nothing that can be readily treated except our tastes, and for those the treatment must be mainly psychological. That remedy is already at work, and the same conditions have also set at work the other remedy, of a more studied production.

It may be philanthropy, but it is also good economic policy, to do everything possible to distribute and add to our knowledge of scientific agricultural principles. The problem is to secure the intelligent application of what we have, but no less to increase our knowledge of principles and of their possible economic value.

The further we are removed from the unsettled times of 1862, the more clearly can we appreciate the wisdom of Justin Morrill in framing the law that founded our present agricultural teaching. The Hatch Act of 1887, by which our experiment stations were brought into existence, is of similar moment. Without the past operation of these two forces to ameliorate our present condition, the situation must have been much more serious.

Any discussion of the relation of any science to agriculture must center around these two institutions—the agricultural college and experiment station. The introduction into farming of improved business methods may be aided by these institutions, but their chief work has been, and will be, the interpretation of science to agriculture. Better business methods are being employed as the more scientific practises add to the attractiveness and certainty of the farmer's occupation.

A survey of the past is strongly suggestive of the idea that the greatest service of biology to agriculture has yet to be performed.

How Other Sciences have Influenced Agriculture

The indebtedness of agriculture to chemistry can hardly be estimated. It is only through the work of the chemist that we have accumulated our information regarding the elements of fertility and the needs of the various crops and their relation to each other and to different soils. No farmer reads the statement of analysis upon the fertilizer sack without thereby receiving immediate aid in the chemistry of his farming, and the greatest aid was given through the information that enabled him to make an intelligent choice of the fertilizer to be used.

To the bacteriologist we owe our understanding of the nature and successful cultivation of leguminous plants. The science of dairying, the handling of milk and manufacturing of milk products, is alike indebted to chemistry and bacteriology.

The physiologist has joined the chemist to qualify the farmer to convert his crops into animal products with the greatest economy, and new suggestive results of laborious investigation are constantly being added.

In biology, we find that horticulture is largely based upon botany. In fact, at the time the land-grant colleges were established, if we except perhaps the chemist, the botanists were the only scientists prepared to teach anything of direct value to agriculture. The knowledge of the origin and relation of varieties and their distribution and adaptability has enabled horticulture to become the most truly scientific of all branches of agriculture.

The service rendered in the study of weeds and devising methods of controlling them has been an important one in making for the fullest and best use of the resources in the soil. Botanists and horticulturists have also introduced many foreign plants of great value in the garden and in the field. As an example of this, we have the alfalfa plant, more recent importations of which seem likely to bring into use some western sections until now regarded as practically waste.

The main, if not the only direct service of zoology has been given through the subject of entomology. Although some of the most dangerous enemies of plants are still beyond control, such as the boll weevil, yet their habits are understood and the crops on which they prey can still be grown with only a fraction of the loss that would be sustained had the habits and life history of such pests not been made known. Other pests have either been eradicated or rendered so nearly controllable as to permit of our safely disturbing the balance of nature by devoting large areas to special crops of such plants as are not encouraged in the natural state.

The Zoologists' Inability to Aid Breeders

We should naturally expect zoology to throw considerable light upon the laws of heredity and upon possible methods of so modifying forms and functions of our animals as to give us more intelligent control of those great factors in agriculture. It is true that a most wonderful improvement of all classes of farm animals has been effected; from a few unpromising native stocks, numerous and distinct varieties have been evolved, each one having distinctive characters of value, either in special adaptability to specific conditions and systems of agriculture, or in capacity to yield a superior product, or, as is true of many breeds, combining some degree of excellence in both respects.

In this fascinating and valuable work, however, there has been little or nothing that could properly be called scientific, unless we should regard as science an accumulation of facts regarding occurrences the explanations of which have not been attempted by the breeders and not altogether successfully undertaken, as yet, by the zoologists.

The fact that zoology has given so little that could be utilized by the breeder is no reflection upon the zoologists. Their problem has been a difficult one, and until a science assumes a form of some definiteness, it is too early to expect any of its principles to be followed out into their operation in economic affairs, particularly when, as in zoology, supposed facts are being dethroned and the evolution of the science seems hardly begun.

The discoverer of important principles can not be expected to also assume the duty of interpreting his science to practise. He works for the acquisition of knowledge and the understanding of natural law in its broadest relations and is seldom qualified to give a scientific aspect to productive labors, even if willing to attempt such a task.

It can truthfully be stated that biology, as one of the sciences, is the newest and least definite of them all, unless we except, perhaps, psychology. This is not because great minds have not been occupied with it, for what other study has engaged such illustrious and widely-known men as Darwin and Wallace and Spencer and Galton and Huxley of England, and such as Lamarck in France and Weismann in Germany?

This retarded development has no doubt been largely due to the fact that biology requires all the other sciences as its servants, and it is only as chemistry and botany and physics and geology have progressed that the biologist has been able to find satisfactory data and material for his attempts to reveal the nature and origin of the various forms of life.

It is true that Darwin studied very closely the work of British stock breeders and referred largely to their work in his subsequent writings to explain and illustrate his theory of the origin of species through natural selection. The principal part of the constructive work of British stock breeders, however, had been done in the first half of last century, and the indebtedness of stock breeding to Darwin was by no means so considerable as the service that industry afforded to the naturalists of the time and to Darwin in particular.

It was not until 1859 that the "Origin of Species" was printed. Remembering, then, the revolutionizing aspect of the first reasonable explanations of the development of the forms of life, and the difficulties opposed to the general acceptance of natural selection as the main evolutionary factor, it is not very surprising that the economic value of such truth has received scant attention.

To interpret a science to an industry requires some individuals interested and qualified in both fields. If botany and zoology, in former years, attracted any men really conversant with agriculture, their full endowments have been devoted to some of the numerous engrossing and fascinating questions of pure science. So we find that until ten years ago it could scarcely be said that any scientific students of heredity were seriously attempting to serve agriculture.

The men who had done so much in the molding of animal form could not be called scientific; complete strangers to any conception of the physical basis of heredity they worked solely as directed by their own experience and such meager teachings as were obtainable from their predecessors. What little constructive work had been accomplished in the plant kingdom was effected by self-taught men of unusual natural endowments for the work.

It would be a serious mistake to lose sight of the fact that wonderful improvements had been effected by development and improvement of numerous varieties of both plants and animals long before any physiological explanation of heredity was attempted. It is quite clear, however, that the principles underlying the achievements of those earlier self-taught master breeders were very imperfectly understood as principles; indeed, it did not seem to them that a satisfactory explanation of their experiences could ever be forthcoming. Breeding was not an art based upon science, but was purely an artistic calling. This being true, it has been impossible to prepare younger men to continue the valuable labors of best breeders, and the most gifted workers with plants and animals have been unable to impart to others the equipment with which they entered into their work. Their successors have been drawn from such men as possessed similar natural endowments and who happened to be so placed as to be encouraged to utilize their qualifications in the betterment of plants or animals, and plants and animals comprise all the objects and instruments of the agriculturist.

The Possibilities of Better Breeding

In our present solicitous and mercenary interest in agriculture, it is not needful to explain the desirability of in any way adding to the value and amount of the plant and animal products now coming from our farms. One paragraph from Mr. Burbank will suffice:

> It would not be difficult for one man to breed a new rye, wheat, barley, oats or rice, which would produce one grain more to each head, or a corn which would produce an extra kernel to each ear, another potato to each plant, or an apple, plum, orange or nut to each tree. What would be the result? In five staples, only, in the United States alone, the inexhaustible forces of nature would produce annually, without effort and without cost, 5,200,000 extra bushels of corn, 15,000,000 extra bushels of wheat, 20,000,000 extra bushels of oats, 1,500,000 extra bushels of barley and 21,000,000 extra bushels of potatoes.

Even more striking increases would be the result of an increase of one per cent. in the amount of human food that our animals now yield from the plants produced for them.

The past ten years have greatly changed the relation of biology to agriculture. One cause of that change was the growing need of special varieties of animals, and more particularly of plants, with such new combinations of characters as would especially adapt them to the economic needs of localities of peculiar conditions. Another factor was the great desirability of putting the subject of breeding into a more definite and scientific and teachable form than it had previously had. But the chief cause of the new era, dating from 1900, was the announcement of the wonderful truth embodied in what we know as Mendel's law.

Mendel's Law and the Influence of its Discovery

Mendel had finished his research and published his very striking results in 1865, when the world was too much engrossed with the Darwinian idea to take any serious interest in data derived from a few crops of sweet peas grown in a cloister yard by an Austrian monk.

In 1900, de Vries, of Amsterdam, and Correns, in France, working independently of each other and in ignorance of Mendel's paper, came to the same conclusion as had the pious monk of thirty-five years before, who, in thus having his name associated with his rediscovered findings, was more fortunate than some other scientists who have lived before their time.

The Mendelian law is concerned with the dominance and recessiveness of plant and animal characters. It was clearly shown by Mendel, and later by Correns and de Vries, that, given a single plant with a character we wish to perpetuate, among a hundred of that individual's grandchildren, there can be secured twenty-five that will be counterparts of their unusual grandparent, so far as the one special character is concerned. This percentage is obtained by mating the prodigy with ordinary stock and excluding the resultant hybrids from being fertilized by any but other produce of the same original unusual individual. Another twenty-five per cent. will be equally as capable of reproducing the opposite character of the individual from which they sprang. The remaining fifty per cent. appear true to the type of their hybrid parents, but, like them, reveal their actual identity when their offspring follow the same unusual proportions.

The fact that such proportions can be relied upon added a new feeling of certainty and greatly encouraged attempts to perpetuate and multiply various features of plants. Of course, in the first generation, the prized character of the parent may be recessive or prevented from asserting itself by the more powerful opposite, and, until it was known that one-fourth of the next generation might return to the character in question, many attempts to breed in new features were abandoned after the apparent failure of the first cross. Instances of the operation of the same law were found in the animal kingdom.

Castle found that in guinea-pigs the extra length of hair was dominant over short hair which reappeared in Mendelian proportions in the succeeding generation. Albinism and smoothness of coat were also found to be inherited as recessive Mendelian characters. But of even greater interest than these unusual proportions is the exhibition of inheritance by unit characters. When we see length of hair being inherited independently of its color, and each of these independent of arrangement as to roughness or smoothness, we begin to realize the vast number of unit characters that go to make up an organism.

The unusual proportions, occurring so nearly accurately in large numbers, were highly interesting to the biologists and very suggestive to many persons not previously interested either in botany or zoology.

Mendel's law was of the greatest importance in pure science because any explanation of the fixed proportions must be based upon the nature of the gametes, and much new theory and research was undertaken to ascertain the basis of such seeming unnatural exactness of proportion.

If we assume that the gametes produced by hybrid individuals are pure to one or the other of the parental characters, the explanation of the Mendelian proportions is comparatively simple. Such assumption, however, is not justifiable in the light of our present knowledge. A satisfactory explanation of the basis of this law will be possible only after the discovery of several new facts regarding the behavior and identity of the component parts of the reproductive cells. This same line of research has also been suggested by the more recent development of our knowledge regarding the accessory chromosome. Such research demands the use of the most perfected instruments and the exercise of the finest technique. It requires an impartial and truly scientific mind, and it is, therefore, very gratifying to find that most of the facts being added to our knowledge concerning hereditary processes in these connections are furnished by American investigators.

The Optimism of 1900

Within a very few years, after 1900, numerous investigators found the Mendelian law to be operative for a wide variety of characters and in many species of plants. Evidence was also forthcoming to show that the same was true of some characters of farm animals.

The air was filled with expectancy, for, since so many things were known to be inherited by Mendelian proportions, it was quite generally assumed that all inheritance was of the same kind. Breeding was no longer an art, nor even a science, but a simple application of mathematics. True, our knowledge of the *modus operandi* of all these occurrences was incomplete, but Mendel's law appeared to be the key to all facts of inheritance, and nothing of moment could be unknown for more than a few months. Such was the thought of many enthusiastic persons in 1902 and 1903. It seemed as though the great door was soon to be unlocked and reveal to us the truth that should explain all inheritance and all life, bringing a new era in biology and in the many vital studies of man with which biology is so intimately connected.

But even should the scientific explanation of Mendel's law be slightly delayed, there was no reason for the breeder of plants and animals to remain under the old régime; so it seemed to many careful and earnest workers in agricultural lines. The fact that the derivation of the formula was obscure was no hindrance to its utility.

One outcome of the new thought was the organization of the American Breeders' Association. The membership of this association comprised botanists, zoologists, florists, seedsmen, growers of seed corn and other cereals, and also breeders of all classes of farm animals. The time was ripe for such an organization. It was the idea of some of the founders that the spread of the new science would revolutionize breeding practise.

At the second annual meeting of the American Breeders' Association, held in 1905, there were presented such papers as these: "Recent Discoveries in Heredity and their Bearing on Animal Breeding."

This paper was presented by Dr. Castle, of Harvard, a most capable zoologist, though less acquainted than might be wished with commercial breeding.

Another paper was entitled, "Mendel's Law in Relation to Animal Breeding," and a third, "Heredity in the Light of Recent Investigations."

In the 1907 session of the same body, Mr. Spillman, of the Department of Agriculture, in a paper entitled, "The Chromosome in the Transmission of Hereditary Characters," said: "I believe that it will finally be possible to work out the complete relation so that we can get a full understanding of the behavior of hereditary characters and thus breed for improved forms with almost as much certainty as the chemist mixes solutions in order to produce a desired compound." At the same time and place, Dr. Davenport, of the Carnegie Institution of Washington, used these words: "Indeed, the fact that the enzymes of the germ cells, and particularly of the egg, determine hereditary characters, points the way to the modification of hereditary qualities and to the production of this or that character at will."

The expectations of such sanguine persons have not been realized. Considerable progress has been made, but it has been and bids fair to be more in the nature of a steady march than of a sudden flight.

Those who were most hopeful of the sufficiency of Mendelism overlooked three things: that we are not able to originate any specific character desired; that not all characters are transmitted in accordance with the Mendelian formula; and that, except for purposes of research, it is seldom practicable to breed for but one single or unit character at a time. Approved animal form embraces probably innumerable unit characters. So far, the only definitely known Mendelian unit characters in large animals are superficial ones, such as coat characters, which are of no direct commercial importance. The relation of the vital body characters is not understood and no capacity for useful functions has been shown to be a unit character. Even with the low number of three or four useful unit characters known to be Mendelian, the chance of their being combined in a single individual is so small as to be of no interest to a practical breeder.

The difficulties of perpetuating a character according to Mendel's law are much less serious with plants than with animals. Knowing that there is strong probability of a unit character of a plant's being Mendelian, the certainty regarding the rate at which it may be propagated adds greatly to the attractiveness of plant breeding and greatly stimulates the search for and endeavor to produce valuable variations.

The Breeders and Mendel's Law

Mendelism has, therefore, given considerable immediate aid to economic plant breeding. It has served to interest seed growers in biology

—rendering their work more intelligent and more scientific and consequently much more valuable. It has also drawn the attention of scientific workers to economic questions, and encouraged research, planned with some thought for economic interests and yet highly scientific.

Animal breeding has been influenced by Mendelism, chiefly through indirect means. The practical obstacles to rearing of large numbers of animals for the chance of finding some new thing has compelled animal breeders to go at a much slower pace than that set by the plant breeders. The fact that some characters of minor practical value have been shown to be inherited in definite proportions has stimulated an interest and study in other aspects of heredity that explains otherwise mysterious occurrences and dissipates common unscientific ideas that have done much to hinder real progress. Ten years ago when the possibilities of breeding up our farm crops were becoming apparent the accomplishments of breeders of animals were the incentive and patterns for those working with plants. To-day the situation is reversed, and work with plants is seen to be beset with fewer practical difficulties and productive of much earlier returns than equally skillful work in the animal kingdom.

The Question of Transmission of Results of Environment of no Interest to Breeders

Breeders and biologists are still far from unanimous in their opinions of the relation of environment to heredity. This fact is no serious hindrance to the breeder's work, however, except in so far as the heat and confusion which is the main product of discussions of the actual rôle of environment, require energy that could be more profitably utilized in some other way. Although a settlement of the question might permit a clearer conception of heredity and facilitate scientific inquiry, it could call for no considerable change in breeding practise. The majority of animal breeders firmly believe that the effects of environment are transmitted. Mr. Burbank also believes the same of plants; but neither Mr. Burbank nor any animal breeder has attempted a physiological explanation of such claimed occurrences. It is immaterial whether we emphasize environment or selection as the chief factor in the production and maintenance of variations. Both are essential, and to consider the changes in our domestic animals to be the outcome of artificial selection, aided and facilitated by adjusted environments, is quite as satisfying from the breeder's standpoint as ascribing first place to environment. Reliance upon selection, however, has the present advantage of being more nearly explained physiologically than is the other view.

Breeders of to-day, especially plant breeders, recognize more clearly than formerly the dependence of improvement upon the ability to detect and to judge the value of departures from the common types of our commercial plants. This means a greater attention to the study of form and characteristics as a basis of and preparation for work along breeding lines and suggests the need of qualifications of an artistic nature. It was because of natural love for animals and unusual insight into animal life and form that a comparatively few men have been able to establish more than threescore breeds of animals of highest efficiency in the performance of a variety of functions through which the human race is served.

The Principle Involved in New Plant and Animal Creations

It is not necessary to enumerate the accomplishments of Mr. Burbank. Through the magazines the public has already been given an adequate if not an exaggerated account of the achievements of that wonderful man. It is a matter of immediate concern to every one to know the basis of Mr. Burbank's success. Has he secrets which are to die with him? Or are we to have numerous workers to whom life forces are as plastic clay? Do his accomplishments prove to us the economic value of recent scientific work or do they refer us back to principles and methods always known but lightly regarded in our eagerness to grasp ideas announced as sure to supersede all that has gone before?

The answer to these questions interests the workers among plants, and no less the student of animals, because the laws of inheritance are, to a large extent, alike in both kingdoms. To most biologists and breeders the greatest value of Mr. Burbank's work lies in the light it throws upon inheritance and the encouragement it offers to persons whose natural leanings prompt them to identify themselves with commercial or scientific work with plants or animals.

The best opinion seems to be that the effect of Mr. Burbank's work will not be to revolutionize breeding practise, but that it does mark an important step in the complete adaptation of plants and animals to all the needs of man. It does this by demonstrating what may be done in the light of knowledge that has been always with us, but seldom appreciated.

Professor Kellogg, of Leland Stanford University, a biologist of standing, and quite intimately acquainted with Mr. Burbank and his work, writes of it in these words:

> No new revelations to science of an overturning character; but the revelations of the possibilities of accomplishment, based on general principles already known, by an unusual man. No new laws of evolution, but new facts, new data, new canons for special cases. No new principle or process to substitute for selection, but a new proof of the possibilities of the effectiveness of the old

principle. No new categories of variations, but an illuminating demonstration of the possibilities of stimulating variability and of the reality of this general variability as the fundamental transforming factor. No new evidence either to help the Darwinian factors to their death-bed, or to strengthen their lease on life, for the "man" factor in all the selecting phenomena in Burbank's gardens excludes all natural factors.

Most of Mr. Burbank's creations are originated by the crossing of existing forms. In a large number of hybrids there is almost a certainty of their being some chance individual of useful character. "In one year he burned up 65,000 two- and three-year-old hybrid seedling berry bushes in one great bonfire, and had fourteen others of similar size."

About the same time that the Mendelian law was rediscovered the word mutations came into use, and it is such a useful word that it is now widely used outside of biology. The fact that plants and animals produce distinctive characters not connected with the ordinary form by intermediate stages is perhaps of greater importance than any other announcement since the publication of "The Origin of Species." Although in a sense opposed to Darwin's conception, the examination of the change in species through mutations as given by de Vries would, in all probability, have been most warmly received by Darwin, because it is a reasonable amendment to his maturest attempt to enunciate the laws of nature.

The fact that mutations do occur, and that they may properly be considered the foundation of elementary species or varieties, as shown by de Vries, is of the highest economic significance. It is only through procedure based upon this principle that lasting results have been obtained by even the most careful selection and improvement of farm crops. Because of the violation of this principle, much conscientious effort has failed to originate even a single variety of lasting value.

We now recognize that in the creations available we have the beginnings and the possibilities of all we seem likely to want or need in the way of new varieties or types of plants or animals.

From a field sown with a supposed pure variety of Swedish barely, Nilsson has isolated and established a number of separate and distinct types, each one having some features of utility that renders it superior to the crop formerly grown in the locality for which it was designed. Here, too, the "man" factor was the chief factor. Nilsson's work especially suggests that the beginnings of all we need are to be found by those who have the skill and the diligence to detect and use them.

In a similar instance, a worker in an American experiment station has isolated a number of types of cotton of distinct usefulness from a field of what had been regarded as a standard variety.

This conception of the origin of varieties emphasizes the single individual rather than the group, and necessitates such intimacy with plant or animal form as will qualify the breeder to recognize and utilize the wealth of material always at hand. And it may also be said that it was only when, through a recognition of this principle, plant breeders began to emulate animal breeders by basing their work upon the individual rather than the group, that lasting results were forthcoming.

This conception also places within the reach of every farmer the means of developing varieties of field crops possessed of characters of especial adaptability to his own land and looks toward more numerous seed farms and the almost negligible difficulty in securing for each field the seeds of varieties of maximum value and productive of maximum yields.

Although the occurrence and use of mutations are less fully understood in animals, it affords a sensible explanation of the most of the progress of animal breeders, and clearly shows that after all, even to a greater degree than we had ever before realized, our chief dependence is upon the exercise of the "man" factor, in detecting and properly estimating the possibilities always available to those who truly desire and are qualified to use them.

Agriculture consists of dealings with plants and animals. The nature and behavior of a plant or an animal is determined and controlled by its inheritance and its environment. Heretofore, the inheritance has been but little understood and interest and effort have centered chiefly around environment. The possibilities of that factor and the possibilities of profiting by its control have therefore come to be well understood. Considering this, it is not strange that the other factor, of inheritance, being little understood, should often have been regarded as of minor importance.

There is still much to be added to our knowledge of inheritance, but the new light of the past decade shows that the man factor at work in directing inheritance may be at least equally as productive as when applied through environment.

It is unsatisfactory to attempt to indicate how the use of this newly perceived power will be evidenced.

The Use of More Definite Knowledge of Heredity

The greater attention to the securing of varieties of crops that give maximum returns of maximum value will add greatly to the productiveness of our lands, and the increase of yields can be supported by soil resources now going to waste; the effort to raise yields by this means will encourage such interest and study as must precede intelligent conservation. It does not seem likely that new creations will occur in field agriculture as have been produced in horticulture, though our knowledge of the origin and inheritance of characters is already being utilized to develop such new varieties of old species as will be adapted to the alkali and semi-arid and otherwise unproductive areas, and thus add greatly to the production from large areas that can never hope to be brought under irrigation.

The securing of seed to produce maximum yields is a matter that has to be canvassed for each particular field and for each particular type of farming necessitated by local conditions governing production and marketing.

In the animal kingdom the new conception of heredity may produce new strains and new breeds to meet newly created demands, or to meet the requirements of localities not fully served by existing types.

The length of time between generations of animals, and the great number of characters that must be considered make it appear that animal breeding, even more than plant breeding, must still remain an art. It is as true to-day as when stated by Darwin fifty years ago, that,

> not one man in a thousand has accuracy of eye and judgment sufficient to become an eminent breeder. If gifted with these qualities, and he studies the subject for years, and devotes his lifetime to it with indomitable perseverance, he will succeed and may make great improvement. If he wants any of these qualities, he will assuredly fail.

It is not in the appearance of eminent breeders, however, that the greatest hope of the future lies. Most of our past progress has been effected as a result of the distribution of surplus stock of eminent breeders, who knew nothing of the science upon which their work was based. Naturally gifted breeders of the future will be able to accomplish still more, because, as a result of study, they may come to have the proper appreciation of fundamental facts which they could otherwise have attained only by experience extending over a large part of the periods of their activities.

In both animals and plants we may look for advancement through the elevation of the best existing types, but a still greater economic advancement may be expected through the discarding, by the majority, of their inferior stock, in order that they may procure the instruments of greater worth, and so emulate the practises of the more progressive of their acquaintances.

This progressive attitude will come as a result of the more general and the more practical appreciation by the many, of the faith in heredity and selection that has been the cornerstone of the success of the few in the past. It will be accomplished by the spread of biological knowledge concerning heredity. It is true that that knowledge is in imperfect form and that we are still unable to originate what we desire, but such significant facts as are fully established shed sufficient light to dispel the darkness and mystery that still prevent over ninety per cent. of our farmers from entertaining that conception of the influence of heredity that is essential to good economic practise.

The greatest service of the biology of the past decade consists in having placed the science of the rearing of plants and animals in good pedagogic form. The placing of the art of breeding upon a teachable, scientific basis, and the realization of what is possible through the fullest exercise of the man factor, gives a very hopeful aspect to the agriculture of the future.

It is to be regretted that our students of heredity and our breeders are not in closer touch with each other. Though the responsibility for this lack of intimate association rests with both parties, I am inclined to think that the biologists are most at fault. In the first place, some of those most sanguine of a complete revolution in breeding practise destroyed what confidence the agriculturists had in them by extravagant and unwarranted predictions and by recommendations that were altogether impracticable. Following this extreme optimism, the same men, during the past few months, have evidenced a pessimistic attitude and, what is worse, have not refrained from expressing their reactionary ideas to the people who were beginning to share some of the former optimism. These pessimistic utterances are based upon data concerning supposed non-inheritance, which data, when not rejected by the practical breeder, are to him suggestive of contrary conclusions. This unfortunate condition is attributable to the disposition of the teachers to discuss the higher debatable points with pupils who have not yet had time to master the elements.

Since the passage of the Adams Act in 1906, much new work has been inaugurated that has for its object the establishment of the right relations between science, and especially biological science, and agriculture. Some of the experiment-station projects have yielded principally negative results, but are none the less valuable on that account. More and better trained workers are needed, and this fact will no doubt bring to the aid of biology and agriculture many capable workers such as have heretofore been discouraged by the lack of opportunities to make themselves useful in this field.

"The achievements of 'pure' science in one generation constitute the formulæ of the 'applied' science of the next." These students of applied science are also certain to be of great service to pure science. Some of the most valuable scientific conclusions have been derived from the results and carefully kept data of experimenters engaged in work carried on for commercial advantages. Continued additions to the science, as worked out into their applications, will continue to modify farm operations.

But it is not alone through agriculture that the world is increasingly indebted to our biologists. If ninety per cent. of our farmers are hampered in their work by their present ignorance concerning heredity, it can be said with equal truthfulness that over ninety per cent. of our entire population live less intelligently and therefore to less purpose than they might live if, for the almost complete ignorance of the hereditary processes there could be substituted a reasonable conception of the things that connect the individual with his ancestry and which show that the welfare of the race, while advanced by the improvement of the individual, is still of greater moment than that of any one individual, and conditions which are seriously detrimental to the individual are not infrequently beneficial to a large number of the race.

The American Breeders' Association is an organized agency working to bring human needs and industries into more intimate relation with the fundamental science of heredity. One branch of the work of this association, of vital importance to the nation, has been given some prominence in late magazine numbers. This is the study of human inheritance as carried on by the association's committee on eugenics.

The objects of this committee are "to investigate and report on heredity in the human race; to devise methods of recording the values of the blood of individuals, families, peoples and races; to emphasize the value of superior blood and the menace to society of inferior blood; and to suggest methods of improving the heredity of the family, the people and the race."

The personnel of the committee is a guarantee that the matter will be thoroughly studied and that there will be no premature recommendations of legislation. David Starr Jordan is the chairman of the committee and Professors C. B. Davenport, Castle and Kellogg are among the members. Their plan is to first study the situation and effect a reform in the tabulation of vital and social statistics, then to work for the education of the race upon the facts of human inheritance. The situation is well expressed by the secretary of the committee in a recent publication:

> A *new* plague that rendered four per cent. of our population, chiefly at the most productive age, not only incompetent but a burden costing one hundred million dollars yearly to support, would instantly attract universal attention, and millions would be forthcoming for its study. . . . But we have become so used to crime, disease and degeneracy that we take them as necessary evils. That they were, in the world's ignorance, is granted. That they must remain so, is denied. Vastly more effective than ten million dollars to "charity" would be ten million to eugenics. He who, by such a gift, should redeem mankind from vice, and suffering, would be the world's wisest philanthropist.

IS EUCLID'S GEOMETRY MERELY A THEORY?

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As there are creeds in religion, so there are creeds in geometry. Most of us pin our faith upon Euclid, whose masterpiece of reasoning is still, after twenty-two centuries, the wonder of the world. The system that Euclid founded stands, as it were, four-square and solid; it meets every need in the only kind of space that we practically know. Over against this edifice, the modern geometries of hyperspace have been reared, from foundations which we Euclideans regard as fantastic. They are intangible structures, like the towers and battlements of a region of dreams.

The present writer holds no brief in favor of a fourth dimension of space. Hypothetical realms, wherein the dimensions of space are assumed to be greater in number than three, yield strange geometries, which are only card-castles, products of a sort of intellectual play, in the construction of which the laws of logic supply the rules of the game. The character of each system is determined by whatsoever assumptions its builder lays down at the start. The illustrious Euclid himself, whom none would rank as visionary, would probably set no great store by these hypergeometries. If he were to return to earth to-day, his interest in them would be that of a retired chess-champion who perceives that his old style of play has given rise to new varieties of the game. Nothing from out this fairyland of thinking could endanger Euclid's prestige; he might contemplate retirement on a professor's old-age pension.

Nevertheless, as soon as Euclid had viewed modern geometry throughout its entire range, the mere suggestion of a pension would in all likelihood ruffle his spirit. For by that time the master would know that geometers no longer blindly accept his teachings; that, moreover, our real space holds mysteries of which he never dreamed. When finally he should discover that experts have arisen who would undertake to instruct him at his own game, he would investigate the massive non-Euclidean systems—the Lobachevski-Bolyai or pseudospherical geometry, and another, the spherical, invented by Riemann—no mere card-castles, but valid in their application to every known space-condition of the universe. Like the rest of us, Euclid would ask himself: In which of these varieties of space does our actual universe belong?

Now, Euclid's geometry is, of course, something more than a game. Its rules—the twelve axioms and five postulates—taken as a group, Euclid might well be proud of. Most people believe that the whole body of his proof rests upon them as upon an eternally established foundation. Eternity is too long to contemplate, but we are certain that to the present time, in no instance, have these seventeen assumptions, when correctly used, ever led to a detectable error. His reasoning is always consistent in itself, always in perfect accord with the known laws of mechanics. One does not feel that the system is a Mahomet's coffin, hovering unsupported in mid-air; it seems to rest on the solid earth, and very firmly. Where, then, is any weakness in the foundation that he laid?

Possibly, in his sleep through the centuries, Euclid has turned over once or twice at doubts, first raised by Ptolemy in the second century A.D., who never became quite convinced that a certain momentous statement was perfectly self-evident, a statement which Euclid used without proving. Apparently it was an afterthought with Euclid in the first place, for not until he had reasoned himself well into the heart of his subject did the need for it, or for something like it, become imperative. Then he asserted quite dogmatically that: *Through the same point there can not be two parallels to the same straight line.* Ptolemy, hoping to strengthen Euclid's foundation, tried to prove this parallel postulate, but concerning the outcome, Poincaré, about eighteen centuries later, has recently said: "What vast effort has been wasted in this chimeric hope is truly unimaginable. Finally, in the first quarter of the nineteenth century, and almost at the same time, a Hungarian and a Russian, Bolyai and Lobachevski, established irrefutably that this demonstration is impossible; they have almost rid us of geometries 'sans postulatum'; since then the Académie des Sciences receives only about one or two new demonstrations a year."[1] The parallel postulate, then, is a weak spot in the Euclidean system. The demonstration that beyond all doubt no proof of its correctness can be devised was an epoch-making discovery. Bolyai's share in this event took concrete form in a brief appendix to a work by his father, published in 1831. Halsted characterizes this document as "the most extraordinary two dozen pages in the history of human thought."

Our chief concern for the next few moments will be to comprehend why the truth of the Euclidean postulate can not be established by argument. After that, I shall try to show why it is not self-evident. These steps taken, I believe that the reader will agree with me that, since it can not be proved, one may freely choose some other postulate in its stead, and thus develop a different geometry every whit as trustworthy.

[1] Poincaré, "Science and Hypothesis," transl. by G. B. Halsted, p. 30; where a clear account of these geometries will be found.

Let no one suppose, however, that the least dispute has ever arisen as to what parallel lines are. Euclid defined them as: Straight lines which are in the same plane, and which, being produced ever so far both ways, *do not meet*. All geometers accept this definition, just as at whist every one agrees on the meaning of certain terms—calls a spade a spade, and so forth. To the brilliant young Lobachevski no good reason presented itself why through a given point there should be only one such parallel to a given straight line. He accepted all Euclid's assumptions except this one, in place of which he substituted a contradictory statement of his own making; he hazarded the novel assertion that: Through a given point there *can be two parallels* to the same straight line. On this foundation he erected a new geometry, building proposition upon proposition until he had reared an edifice as coherent and in every respect as perfect as the geometry of Euclid. What conclusion may we draw? This: had Euclid's postulate been eternally true, then to deny it while holding to his other axioms would have led Lobachevski into endless inconsistencies. But the fact that its contrary

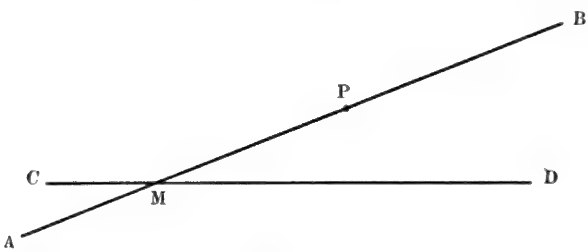


FIG. 1.

was substituted for it and a new geometry developed without encountering any logical obstacle shows that the postulate rests on nothing more fundamental than itself; shows that it swings, so to speak, in mid-air, unaffected by Euclid's other assertions. No statement can be proved by itself alone; consequently, this statement, having no logical connection with any other, can not be proved at all. Moreover, this achievement, broadly comprehended, set the entire Euclidean system aswing without support; its supposed connection with the solid earth was a fact only of the imagination.

I promised, in the next place, to show that Euclid's postulate lacks self-evidence. In Fig. 1 there is a point *P*, lying without a straight line *CD*. Another straight line *AB* passes through this point, and we shall imagine both *AB* and *CD* to be produced ever so far both ways.

Now *AB* will be parallel to *CD*, if they conform to Euclid's definition of what parallels are, namely, if both lines are straight, and in the same plane, and being produced indefinitely, do not meet. In that position the lines would be parallel, but let us start from the position shown in the figure, where the lines we are talking about do meet at the point *M*, and let us imagine further that this point of intersection *M* travels along the line *CD*. If then we keep turning the line *AB* slowly round the point *P*, eventually the point of intersection *M* must disappear at one end and reappear at the other end of *CD*, it matters not how far the two lines have been extended.

The assumption hidden in Euclid's assumption is that there can be one and only one position of the moving line *AB* at which it will be parallel to *CD*. Lobachevski contrariwise assumes that *AB* will have to be turned through a finite angle *after* parting from *CD before* it intersects with *CD* again. That angle to be passed through gives Lobachevski the opportunity of postulating not only two parallels to *CD*, but an aggregate of parallels, all passing through the point *P*. The same argument may be presented a little differently and more clearly perhaps, as follows: Imagine *AB* at first not merely parallel but at all points equidistant from *CD*. Will not *AB* have to dip through a certain distance before it can meet *CD*?[2]

This problem, apparently so simple, is of such a nature that neither opponent can prove his assertion. It will be observed that when Euclid says only one parallel is possible, and when Lobachevski says an infinite number of them are possible, there is still room for a third champion who will say no parallels are possible, that the lines *AB* and *CD* if extended will always meet, which is precisely Riemann's position on the question. The three geometries are thus exactly upon a par; no one of them can establish itself against the other two; and the number of possibilities is complete, for among the assertions "one," "many" and "none," there is no position unoccupied in reference to the mystery of parallel lines; no chance left for any fourth geometry on this basis.

We are now on the threshold of non-Euclidean geometry, prepared, I trust, to enter a new variety of space where geometrical problems work out to results differing widely from those found in the books of Euclid. Compared with Lobachevski, Euclid was more sparing of parallels, and the effect of this parsimony upon Euclid's idea of space is very marked. I know of no better expression for the difference between their notions of space than to say that Lobachevski's space is *roomier*. In Lobachevski's space, if a man whose course was restricted to a perfectly straight line should wish to avoid crossing a perfectly straight road,

[2] Nothing in the definition, as established by Euclid himself, compels one to believe that two parallel lines must be equidistant. The requirements are that they be straight, that they lie in the same plane, and that they do not meet. Euclid discovers that his parallels are at all corresponding points equidistant from one another; but his parallels are peculiar in this respect, and it should be borne in mind that they owe their existence to the postulate which no one can validate.

he might set out in exactly the same direction as the road runs, or he might incline a very little toward it; in either case he would never meet it. This is equivalent to saying that Lobachevski's space is more expansive, more generously given, and if the reader will follow me a step further, I may say that this space becomes roomier increasingly with every step that the man takes forward.

It costs nothing to imagine ourselves entering this domain of Lobachevski; indeed, for aught we know, we may be actually in it now. And it will cost us no more to imagine our expedition equipped with instruments for measuring angles and for drawing straight lines, instruments more delicate and accurate than any that science has yet devised. A series of experiments may then be carried out to illustrate the properties of this hyperbolic region. I shall limit the narrative to some of the results we could obtain:

A. Parallels, really straight lines that never meet, have a point of nearest approach to each other, but if followed in either direction outward from this point, they will be found to diverge, spreading farther apart without limit (Fig. 2).

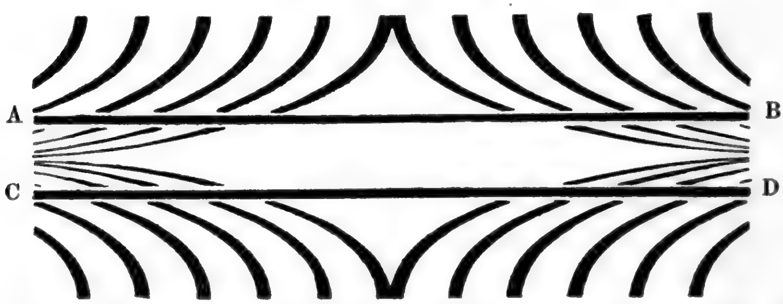


FIG. 2. The lines *AB* and *CD* are straight, as may be seen by viewing the figure from one side with the eye close to the paper. They are in the same plane and will never meet. Yet by an optical illusion we here obtain within a small compass the same appearance as would be furnished by two parallels to an eye located in Lobachevski's space and capable of surveying a tremendous stretch of the parallels from a very great distance. The diagram probably has no reference whatever to non-Euclidean geometry. It elucidates mental, not physical, phenomena.

B. If two perpendiculars are erected on a Lobachevski parallel, they will spread away from each other, becoming farther apart the farther we extend them outward from the base line.

C. With this base line and the two perpendiculars, we might think we had three sides of a rectangle, but no—for after making three of the corners right angles, the fourth must needs be an acute angle. A true rectangle is impossible (Fig. 3).

D. We can, however, draw a straight-sided triangle. In Euclidean space the internal angles of such a triangle, added together, always equal two right angles, but here they fall short of two right angles, and the larger the triangle, the less the sum of its internal angles. Logically pursued, the largest triangle possible would have all its sides parallel and all its angles zero.

This last statement has touched the verge of infinity and that is no doubt treacherous territory. Coming back to our real universe—How can we prove that Euclid is right about it? The real universe is large. If, like the adversary in the Book of Job, we could go to and fro in the great world and walk up and down in it, then we might decide the controversy. But the limit of man's present astronomical measurements is only about 30 light-years—176 millions of millions of miles. Within this compass he has observed no drift or change in the direction of rays of light. If in our real space parallels are not exactly and everywhere equidistant, Euclid's geometry is incorrect. The slightest deviation in parallels would give the victory to Lobachevski or else to the third competitor, Riemann. The three justly claim equal con-

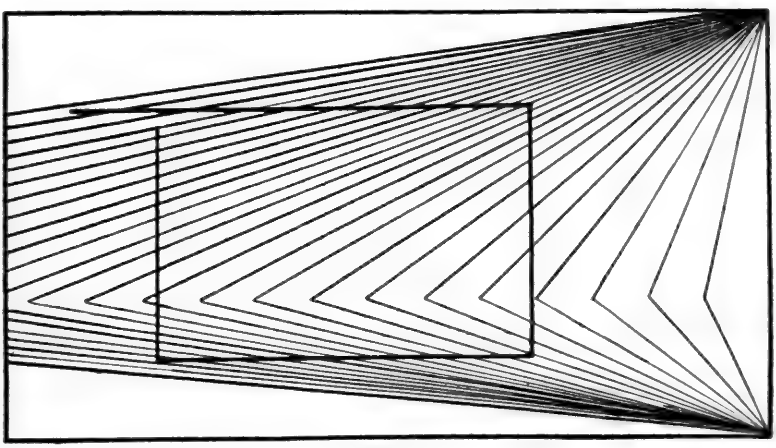


FIG. 3.

sideration in the light of present knowledge. Could such drift, if real, escape human observation? Yes; first, because our instruments are not absolutely accurate; and secondly, because eyesight is no infallible test.

If the human eye could survey a sufficiently tremendous expanse, then parallels running through it might present the appearance of the hyperbolic curves limiting the black and white areas in Fig. 4. These curves may represent, and in certain respects they do simulate, the parallels of Lobachevski. They are, to be sure, not parallels, for parallels are by definition straight; however, by placing the eye an inch and a half above the center of this figure, these lines can be made to look straight—a fact that confirms the statement that eyesight is not an infallible test of straightness.

Fig. 4 will do good service if it enables us to understand what people mean when they assert profoundly that "non-Euclidean space is curved." We ought to discard this misleading, though very prevalent, expression, for it is as confusing as to say that space is straight, or cold, or pink. It certainly sounds absurd to call a straight line curved under any circumstances, and so it is, so long as we confine our thinking to any one kind of space. But in carrying lines over from one space to another, there is this change of emphasis. For example, the parallels of Lobachevski, when transferred into Euclidean space, cease to be parallels and become, as shown in Fig. 4, hyperbolic curves.

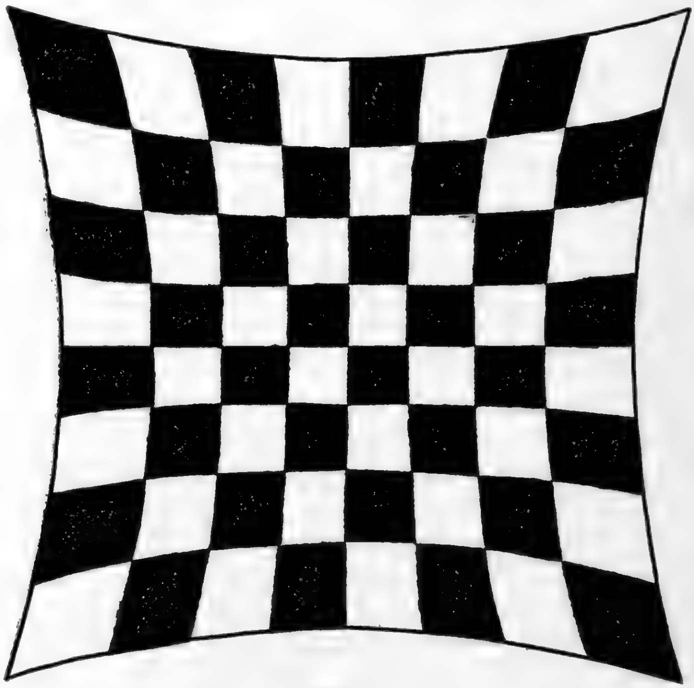


FIG. 4.

Contrariwise, the parallels of Euclid, transferred into Lobachevski's space, retain merely their secondary property of equidistance, and pass under the name of equidistantials, since they are no longer true parallels, nor even straight, but rather they are very long curves.

We read in the Arabian Nights of the magical carpet of Tangu, which could be made to fly incredible distances by wishing it to do so. Imagination can furnish us with a similar carpet that will flit from one realm of space to another. Suppose then that our carpet is being woven at a non-Euclidean factory. It should be pliable, but it must not stretch, and it must possess truly princely size, having leagues upon leagues of surface. When spread out, it must lie perfectly flat and smooth in Lobachevski's space, but if transported into Euclidean space, it can only lie crinkly and fluted around its edges, for this environment, though boundless, is less roomy and the expanse will be too niggardly to accommodate the carpet's ample proportions. Suppose, in addition, that the carpet, while at the non-Euclidean factory, receives on its surface a checker-board pattern of black and white squares separated by criss-cross parallel lines, truly straight lines in the sense of being the shortest distances between points. The squares can not be perfect rectangles because, as already observed, such figures are not among the non-Euclidean possibilities. In Euclidean space, they would look like the black and white areas in Fig. 4. The figure is not, however, a perfect representation, because the carpet could not be made to lie flat in Euclidean surroundings without violent stretching, while to distend it would be to destroy the spatial relations of the lines of the pattern, after which, for geometrical purposes, it would no longer be the same carpet.

Spread out the carpet, nevertheless, as evenly as Euclidean space allows. No part will lie perfectly flat, of course; and only a limited portion can be made to lie smooth; the outlying portions will refuse to be spread out and must remain in folds. The smooth portion will then be slightly curved into the shape of a saddle, trending upward at front and back, and rolling off downward on either side, the whole forming a surface of constant negative curvature, called by mathematicians a pseudosphere, and being simply Lobachevski's plane surface after its transportation into the Euclidean environment. Upon such a surface we can draw diagrams suited to illustrate any problem in Lobachevski's plane geometry just as for Euclid's plane geometry we make use of the flat surface of a blackboard. Lines drawn on the pseudosphere can not be straight; they can only be the *straightest* lines that the surface will allow; but, limiting our discussion to lines lying wholly within the surface, these straightest lines will still be the shortest distances between points in the surface and would remain so, even if the surface were crushed into a wrinkled heap.

We do not know upon what kind of a surface Euclid drew his diagrams, perhaps upon sand, but it is reasonable to presume that it was approximately flat. Had he used a pseudospherical surface, he might have developed a different conception of space. Had he, on the contrary, chosen a sphere, he might have arrived at the geometry of Riemann, for the plane surface of Riemannian space becomes simply a sphere under Euclidean conditions. The opportunity is so favorable just now that I may be permitted briefly to set down some of the results derived from this third type of geometry. Obviously, the straightest line that one could draw upon a sphere, as, for instance, by stretching a string between two points on the surface, would, if extended, go completely round and form a great circle. Certain conclusions follow:

A. No parallels are possible; all great circles (straightest lines) must somewhere meet.

B. Euclid's axiom that: *Through any two points only one straight can pass,* is, in most cases, correct; but when the points chosen are diametrically opposed, as are the poles of the earth, then an infinity of great circles cross at such points, and any two of these lines enclose a space.

C. Concerning triangles, the internal angles are together always equal to *more than* two right angles, the excess increasing with the size of the triangle. Rectangles are impossible. Two plane figures (except circles) can not be similar in shape unless equal in size.

D. The Riemannian space is not infinite in extent, but returns into itself. It is, however, boundless; one could never come to the end of it. With eyes adapted to enormous distances a creature looking in any direction might see the back of its own head.

E. On the hypothesis that our own universe is of this nature, "a finite number of our common building bricks," as Halsted says, "might be written down which might be more than our universe could contain." And if our earth should increase in bulk, at last the lower surface would advance upon us from above, and, reaching us, would fill the whole universe.

It is commonly supposed that these peculiarities of Riemannian space are easier to conceive than are the results at which Lobachevski arrives, but this is probably not the case. Long ago, Beltrami discovered that the whole space of Lobachevski, notwithstanding that it is infinite in extent in all directions, can be conceived as packed within a hollow globe of finite radius. Imagine, therefore, a great sphere of a hundred yards' radius, with a door leading into it. Looking in, let us suppose that we can discover a railroad track on a trestle extending from the doorway diametrically across to the other side, and a small man—an inch high—standing between the rails and at the exact center of the sphere. Nothing about this view suggests anything but ordinary space to us; it is only for the little being at the center that this enclosure constitutes Lobachevski's universe.

Another assumption is now to be granted: let the man dwindle in size whenever he moves out of the center toward the shell of the sphere. Growing less and less, he would have no size at all upon reaching the shell, but he *could never reach it,* for the length of his stride would lessen in proportion to his lessening stature. To him, therefore, the sphere is infinite in extent. Likewise all other objects—the boards on the footpath, the foot-rule and the keys in his pocket, and the pocket itself—have their sizes determined by their location within the sphere, let only the rails of the track be continuously parallel both according to his and our own notion of things, and also according to Euclid's definition.

Going to and fro along the track, the little man would judge that the rails are not equidistant at all. Applying his shrinkable foot-rule, he would decide that the space between the rails varied in width at different places. He would come to the same conclusion that we have set down, namely, that parallels may at first approach but, following them further, they diverge more and more. All this he would discover and never suspect that his own variable dimensions were the cause of a deception, for would not his surroundings shrink always in proportion to himself? Beltrami's illustration thus attains its purpose by making solid objects expand and contract in place of allowing space itself to grow any more roomy than our Euclidean notions permit.

If Euclid were to return to earth to-day, he would find many geometries, but the three here described would probably interest him above all others. A fitting task for Euclid would be to coordinate this trilogy of systems. With the three volumes spread open before him, he could write a dictionary by the aid of which a student could translate any proposition stated in one volume into the corresponding proposition given in either of the other two. It is at bottom a matter of words, or at least the facts lend themselves to that interpretation. With intense satisfaction Euclid could still contemplate his own geometry. Where long and involved phrases are necessary to convey the idea presented in the other systems, his own ideas are always lucid and tersely expressible. His system is consequently by far the most *convenient,* so much more convenient, that if we should ever discover any discrepancy between it and the facts of the physical universe, we would probably prefer to change our laws of physics or mechanics rather than to adjust ourselves to a less convenient system of geometry.

THE UNDERLYING FACTS OF SCIENCE

By ALFRED SANG

PARIS

SCIENCE originated in the temple; for ages it remained as a mass of detached observations floating in mysticism. The civilization of Greece gave us the broad lines of many of the sciences, but the confinement of knowledge to monasteries, the enslavement of the human mind and the suppression of the wisdom of the ancients during the dark middle ages, deferred the rise of science until within comparatively recent times. From mysticism science has gradually drifted into agnosticism; mysticism cramped the work of the investigator; agnosticism lays no restraint whatever on his mental ambitions. The suspension of judgment on all matters unproven has helped in mighty measure to make theory the indispensable weapon of the scientist in attacking unsolved problems.

The Value of Theory

Theory, based on observation, is an accepted factor of inquiry, and the temporary acceptance of a theory serves as a scaffolding in the building up of knowledge; it is necessary to the work of correlating facts and to train the mind for the discovery of new facts. When we find our theories checked and kept within certain definite bounds, we can assume that we have found the measure of our ignorance and that the truth lies somewhere within the compass of these theories. If a theory is not a logical deduction from facts it should be called a hypothesis.

Nothing has created more prejudice, and thereby done more harm to theory as an instrument of progress, than the easy acceptance by the general public of all novel and sensational theories as proven facts if consecrated by the daily newspapers and the magazines. From the husk of the acorn an oak is postulated, although it may be rotten at the core and worthless. But we *must* theorize because we are built that way. As Tyndall once said:

> Man is prone to idealization. He can not accept as final the phenomena of the sensible world, but looks behind that world into another which rules the sensible one.

The Limits of Conception

In scientific speculation, it is essential that we lose all sense of proportion, of time and of space. No dimension must appear impossible because it is infinitely large or infinitely small; no time must seem impossible on account of its infinite length or of its infinite shortness; the grains of sand of the ocean bed and the bubble capacity of a million tons of soap are crude and inadequate figures of comparison. We must remember that in extra-mathematical investigation we judge everything by human standards, but that in reality anything which can be expressed as a mathematical formula is as simple in nature and in operation as the facts of every-day life. If we do not get away from the habit of setting limits to every conception—limits based upon our own surroundings—we shall find our speculations conflicting with science at every turn.

The knowledge of principles clears the fog in which the speculative mind wanders in search of resting spaces, and the secret of clear conception lies in the ability of ridding oneself of *pre*-conceptions. If in attempting to conceive the speed of propagation of light we bring to mind the speed of a railway train or of a rifle bullet, we set a limit to our mental grasp, just as a student who can not assimilate an algebraical formula without an arithmetical parallel shuts himself out of the higher mathematics.

The greatest limitation from which our forefathers suffered was the rushing to conclusions from analogies, and the shallowness of the results can not be better illustrated than by quoting from a book called "The Art of Metals," published in the year 1640, and at one time considered an authority in matters metallurgical. Referring to blue copperas, or sulphate of copper, the learned author writes:

> It is admirable to see its effect in *Aqua-Fortis*, (in which all Mettals like Salt dissolve and are turned into water) and an occular demonstration of the possibility of the transmutations of Mettals one into another, for with Copperas dissolved in *Aqua-Fortis*, (without any other artifice) Iron, Lead and Tin become fine Copper, and Silver will lose of its value, and be turned into Copper also.

When discussing the principles of physical science we are confronted by a condition which continually vitiates clearness of exposition. Conceptions of energy and of matter are now becoming more and more convergent and we find ourselves in the dilemma of having at times to think of matter as energy and at the same time to describe energy in material terms. The world of science is becoming daily more accustomed to the convertibility of the terms energy and matter; but there is a natural tendency to incredulity, for, as some one recently stated:

> In the estimation of material beings matter must necessarily assume a position of special importance; but nature may not perhaps regard it otherwise than as one of numerous forms of force, between which (as Newton wrote) it "delights in effecting transmutations."

We shall return to this subject later.

There exists a public impression that the dreams of the old alchemists who, with the possible exception of an occasional Paracelsus, sought hap-hazard for the transmutation of the metals, has been vindicated by the disintegration theory of atoms and the discussion of the possible transmutation of one chemical element into another. This is doing altogether too much honor to the alchemists whose only object was personal enrichment; there is no credit due to them; the most extravagant theory may be realized under suitable conditions and in this mysterious universe any condition or concurrence of conditions seems to be possible.

Theories of Matter

For the belief that all matter may have a common origin, we must go back twenty-five centuries to Thales of Miletus and the hylozoistic school; it is another case of the premature leakage of subliminal wisdom. Sir Norman Lockyer can be said to have put the theory into tangible form by his work on stellar evolution which has developed the fact that the complexity of stellar matter is a function of its temperature. The higher the temperature of a star is, the fewer and the simpler are the elements present. Würtz wrote that "the diversity of matter results from primordial differences, perpetually existing in the very essence of these atoms and in the qualities which are the manifestation of them." Ascribing a common origin to all matter would tend to make the formation of new compounds from heterogeneous chemical elements appear more rational.

The problem of the ultimate structure of matter has stirred the philosophers of all ages, Democritus and Leucippus were the real discoverers of the atomic theory, and Lucretius was its poet; but the times were not propitious for its use as a working hypothesis; it was not, therefore, until revived by Gassendi and adopted by Dalton, that it became acceptable to science. As long as the chemist was obliged to work with *molar* masses of matter, his work was unsystematic and in a great measure fruitless; the atomic theory put things in their place and gave the chemist definite *molecular* masses with which to work. The proof of the atom has been its results; we have not here a question of nature, nor a question of form to discuss; the atom is a *fact* in chemistry, even if it has no existence in any conceivable form. Molar masses are continuous aggregates of molecules; molecules are definite aggregates of atoms. The selective qualities of atoms, the phase-rule, etc., belong at present more to chemistry than to physics, and they will, therefore, be left out of the discussion. Molar activity is known by its comparatively slow mechanical effects; atomic and molecular activity are known as heat and other forces, and as we go down the scale of size we find the activity more intense. But if it is unnecessary for the purpose of this exposition to discuss atoms and atomic aggregates, it is very important to understand the rôle of ions.

Positive and Negative Ions

An ion is a charged atom, an atom carrying a quantity of electricity, such, for instance, the dissociated atoms of an electrolyte. Ions can be compared to diminutive Leyden jars, and as it has been discovered that they all carry the same charge and that each atom has the same electrical capacity, the physicist has been enabled to count the actual number of ions in any gas by the electrical properties of the gas. If an ion is electro-positive, it is known as a cation; if electro-negative, as an anion —two old words due to Faraday, which are immediately related to the familiar terms of cathode and anode.

Whatever the essential difference between them may be, the two electrical states (+ and —) may be said to differ chirally only, or, to give a more distinct if rather crude mechanical analogy, one may imagine that two discs, each suspended by a thread in its center, are revolving at a high uniform speed; if they revolve in the same direction they will spring apart as soon as they come into contact, part of their motion of rotation being converted into motion of translation; if they revolve in opposite directions their motions will not interfere, in other words they will be "in mesh." Thus, according to this conception, each is the enantiomorph, or opposite form, of the other; positive and negative charges of ions are equal but opposite. This idea of opposite charges owing their difference to opposite directions of rotation is only a working hypothesis, but is worth keeping in mind.

Distinction between Energy and Force

Having adopted negative and positive ions as the basis of matter, we must now examine the distinction between force and energy before going any further into the sub-atomic world. Force is the action, the manifestation of energy, just as visibility is a physiological manifestation of light. Light, in the abstract, is energy; in the concrete, as something that we see, it is a force. It is propagated as energy and manifested as a force; force, therefore, always implies matter.

As we shall have opportunities to see later, all energies are almost certainly modes of motion. Matter, on the other hand, is perhaps best described as whatever can occupy space, but this description is not suited to all theories. If motion is an essential property of matter, matter might be best described as whatever possesses energy in virtue of its motion; but in this essay the nature of matter will be discussed, and not its structure.

The ether, in which energy is manifested, may be said to have owed its recognition to the impossibility of believing in action at a distance and through a void space. Sir William Crookes at one time suggested a fourth state of matter for the ether; before accepting this theory, however appropriate it may appear, it seems reasonable that all the possibilities within range of our understanding be exhausted; we can hardly expect to understand a fourth state until we have fathomed the relations between the three states which we already know, and also their intermediate forms which immediately precede their critical points of transformation. We may some day be forced to an acknowledgment of this fourth state, although we may never be able to conceive it. It would be somewhat surprising that the ether be in any form known as matter; much more surprising than that matter be, after all, but another manifestation of energy.

It is a common thing for writers to dwell upon extinct theories. History is very well in its place, but in this essay extinct and not-generally-accepted theories will be disregarded in favor of those of more recent growth, or such as may be suggested by the recent discoveries in physical science. On this account it will be necessary, in the first place, to review very briefly the present state of radiology, without a knowledge of which a proper understanding of modern theories would be difficult.

The Facts of Radiology

Credit must be given to the early work of Sir William Crookes on radiant matter for having prepared the way to recent discoveries in this branch of physical chemistry. Credit must also be given to Sir J. J. Thompson, for work on the electric properties of gases, without which many of the important facts of radiology would have remained either undiscovered or barren, to which have been added his many masterly discoveries in the electronic world.

The most studied radio-elements and the most interesting for the present discussion are uranium, actinium, radium and thorium. The distinctive property of the radio-elements is to disintegrate, forming other radio-elements and also a more stable element. The disintegration is not molecular; it is atomic; the atom breaks down, it is destroyed or converted into the atom of another element. Radium is apparently de-energized uranium; the spectrum of uranium is entirely distinct from that of radium and they may therefore be considered distinct chemical elements. The radiations and emanations of all radio-elements being, in a general way, the same, it is only necessary to describe in detail the disintegration of radium, which is the most interesting and complete of all.

The magnet will separate the radiation from radium into three distinct streams, just as a prism will break up white light into its physiological primaries. These three radiations are known, respectively, as α, β and γ radiations, and radiations possessing similar characteristics are given off by all known radio-elements. The α radiation, which appears to be composed of helium atoms, has secondary rays composed of particles, until recently considered negative electrons, but, according to Professor Soddy, by no means finally proved as such for all cases. These particles of the α radiation are probably of relatively large size and are beautifully exhibited by the scintillation of the zinc sulphide in the spinthariscope. The β rays are extremely complex and interesting and their power of penetration is about ten times that of the α rays. The γ rays, which are themselves about ten times more penetrating than the β rays, but do not affect the photographic plate to an equal extent, seem to be produced by the explosive disturbance which takes place at the formation of the β rays, just as X rays are produced by the impact of cathodic rays; in fact, these γ rays are very similar in degree of penetration and in some other properties to the X rays. In addition to the γ rays, the explosive disturbance referred to produces an emanation, a veritable spray of the radio-active element. The emanation is, according to present standards, a form of matter, whereas the radiations can not be positively defined as such if judged by the same standards. The emanation, which is therefore a spray of the radio-element, a vapor, renders any object bathed in it radio-active and the action does not cease until the dust deposited on it has decomposed into radiation and emanation. The most significant product of the disintegration of the radio-elements, however, is helium, which has been mentioned in connection with the α ray; it is a distinct element with a distinct spectrum, perfectly stable chemically and therefore quite unlike the other products of disintegration.

Helium seems to be the state in which the unstable atom of the original uranium at last finds rest. It has been suggested that the helium may be merely occluded, but valid arguments have been brought to bear against the idea, and, if anything, radium would be a true compound of helium and of some other element. It has even been suggested that all chemical elements may be helium compounds. This is a return to Prout's theory, but with helium in place of hydrogen. Contrary to general belief, helium is not exclusively a product of the radio-elements; Strutt has recently succeeded in obtaining a very fair percentage of it from New Hampshire beryl which did not exhibit any measurable radio-activity; it may, however, have done so in the past, the helium remaining occluded.

The speed of decomposition of the radio-elements, or rather of their salts—the bromides and chlorides being the most generally used—is so rapid that the use of chemical methods of analysis is almost hopeless. Radium is comparatively manageable, but actinium, which is said to be at least one thousand million times as active as radium, has a life period of less than eight seconds. It has been suggested that actinium is an intermediate product between uranium and radium.

The Disintegration of Matter

One of the latest developments of the theory of the disintegration of matter is a suspicion, which scientists hardly dare to voice, that there is a continual disintegration of *all* matter, stability being only relative and the new and perfectly inactive gases discovered in the atmosphere being among the most stable elements. It is just as natural for the atom to die as for it to be born; if we accept the latter, we can not deny the former. The atom of matter slowly expends its energy as does a watch-spring in doing the work of keeping time. Matter, according to this theory, is concentrated energy, the dissipation of which is almost too slow for us to detect. This theory has been taken advantage of to try to explain the sun's effulgent shell, and the question arises: when the unstable matter of the sun has completely disintegrated, will it become a globe like ours, dark and relatively cold, a mass of molten iron in the complex slag of which creatures not unlike ourselves shall dwell and dig for mineral treasures, subject to the changed conditions? Has our planet itself been through that state? Such a supposition is certainly no more extravagant than many we have heard, and the scarcity on the earth of radio-active substances and of the rare-earth elements which are such powerful emitters of the more useful light waves, does, in some measure, support such a theory.

However, in order to show the immense periods of time which are brought into question, we might borrow the following impressive example: one cubic centimeter of hydrogen contains approximately 525 octillions of atoms; if 10,000 of these were allowed to escape every second it would take about 17 quintillion (17,000,000,000,000,000,000) years to empty it. Upon a similar basis of expenditure of their contained energy by atoms of matter, it is evident that the detection of this expenditure would be very difficult. Before returning to the ether the electric atom or electron must be studied.

Corpuscles and Electrons

To understand what an electron is, we must imagine an ultimate particle—not a particle of matter, nor a particle of force, but just simply "a particle"—and let us give to this particle the old-time attribute of the atom; let us assume it to be indivisible. This, of course, is only a working hypothesis. This particle considered in the abstract we shall call a corpuscle. If we endow it with energy we shall call it an electron. Quite possibly the corpuscle can not exist except as an electron, or atom of negative electricity. However this may be, we must assume, in order to facilitate the discussion, that a corpuscle is only an electron when it is endowed with sufficient motion, which may be either vibrational or translatory, to manifest itself to us electrically. We shall assume that the abstract corpuscle exists, and that it only becomes an electron when it is energized. Atomic action and the behavior of charged, or rather unbalanced, atoms, called ions, belong as much to chemistry as to physics, but corpuscular motion is purely physical as yet; it has no direct bearing that we know of on chemical reactions. As regards the nature and dimensions of corpuscles, J. J. Thomson has estimated them at one one-thousandth the mass of the hydrogen atom. As regards speed of translation, many radiations composed of electrons approximate the speed of light; this represents almost nineteen million times more activity than the one mile per minute ascribed by Clausius to the hydrogen atom which has already been taken as a standard of comparison. There are some very interesting theories to be derived from the study of electrons.

The Atom and its Metamorphoses

The present theory of the atom as derived from radiology is that it is composed of electrons moving rapidly in all directions and necessarily in constant collision; these electrons are assumed to be held together in each individual atom by a positive force. Differences in the number of electrons in an atom give rise to different elements. Imagine a glass globe of about the same diameter as the dome of St. Peter's, in Rome, with a quantity of grains of wheat shooting about inside in all directions, and acting and reacting by continual collision; the globe itself represents the force which keeps the electrons within the compass of the atom; the grains of wheat represent the electrons. We can, if we wish, assume that the electrons have orbital motions in relation to one another, as regular as those of the planets; it is only a difference in mass and in speed, and the mass being so enormously smaller, it is not surprising that the speed be so enormously higher, and, furthermore, there is no reason for thinking that the same laws which regulate a solar system may not regulate an atomic system. When the atom disintegrates it loses some of its electrons until a balanced system is reached, and it can then be assumed to be a stable atom, of a different element, however, provided the loss of electrons was not complete. If the theory of universal, or almost universal, disintegration and re-formation of atoms is correct, there is a constant outpouring of electrons from all atoms of matter, which even with a liberal allowance of units per second would hardly amount to an appreciable difference in atomic characteristics within historical periods of time, but which, premising a common era of formation for terrestrial elements, might explain the fractional discrepancies in atomic ratios; if such a theory were true, the elements as found in other worlds might have slightly different chemical constants.

As recently suggested by the author,[1] if the atom is continually

[1] *Nature*, February 18, 1909, p. 459.

losing electrons and, therefore, atomic weight, until, a certain critical point being reached, a readjustment takes place resulting in transmutation to a lower element, it may be supposed that the atomic weights of the elements may vary in different worlds of space. The more or less uniform weights found on this planet would be due to the fact that the period of formation was practically identical in all cases. The slight divergences between the theoretical and actual atomic weights in the periodic system would be due to the electron contents having fallen below the contents at the last points of readjustment. The list of the chemical elements arranged in decreasing order of their atomic weights would represent the steps of the degradation from the highest elements having, possibly, atomic weights exceeding 250. It was further suggested that the atomic weights of the elements in meteorites be determined to check the truth of the theory of transmutation by disintegration; as far as known this has not yet been attempted.

It would seem to be rather idle to discuss the possible reasons for the diversity of elements in each chemical group on the assumption that they all originated at one time for each individual body in space from extremely dense elements, themselves concentrates of the one primal element. At most, it is proper to state the theory as follows. As the nucleus of a nebula condenses and cools into a solid mass, the structure of the matter at the center becomes extremely dense and the atomic weights are high; these weights taper off to the surface, which is then of a somewhat irregular and slag-like nature like the crust of the earth and brings to mind many parallel cases in metallurgy. Many scientists hold that the earth has solidified more or less in the shape of a modified tetrahedron; if this be true, it encourages the view of a fairly homogeneous core which may be composed of elements even heavier than radium, thorium and uranium. The radioactive properties of these elements may account for the internal heat of the earth. The view that the bulk of this globe of ours is of similar composition to the crust is not only unjustifiable, but highly improbable; the slag of a steel-making process is a good indication of what there is *not* underneath. The theory of a core composed of elements having high atomic weights will go far to explain the high average density of the earth as compared with that of the crust.

The Electrical Nature of Gravitation

A discovery of inestimable value is due to Kaufmann; he found that the *mass* of the *a* particle *varied with the velocity*. This discovery all but consecrated the old theory that mass, that gravitation, is a form of energy, a mode of motion. There can not be a *manifestation* of energy when the motion is uniform. No motion of energy can be evidenced without acceleration followed by arrest and a reversal of motion, or what is known as "periodic acceleration," pulsation or vibration. We can not measure a uniform motion in a particle moving with the speed of light, but we can measure its acceleration. All forces pulsate; they are all propagated as waves, which set up vibratory motions in matter and thus make their presence evident.

In support of this statement about the nature of mass, which is of such fundamental importance, the words of Professor Rutherford may be quoted:

> If a charge of electricity in motion exactly simulates the properties of mechanical mass, it is possible that the mass of matter in general may be electrical in origin and may result from the movement of the electrons constituting the molecules of matter.

It is to be noticed that Professor Rutherford refers to the electrons as charges of electricity. His words give a full, if concise, definition of the electrical theory of matter which is accepted by the mass of physicists and of which Sir Oliver Lodge is the able historian. When Davy suggested that matter and electricity were kindred phenomena he could hardly have suspected how near he was to the truth as it is seen to-day. The materialists and energists are now on the high-road to reconciliation, and we are permitted to feel that an explanation may soon be forthcoming for the well-known relation between specific heat and atomic weight, and for that existing between spectral phenomena and atomic weight.

The matter of gravitation can not be put aside without a few additional remarks. Lord Kelvin, by calculation, has ascribed to the ether a weight of one-thousand-billionth of a gram per cubic meter. This is not very much, and can give little encouragement to Lothar Meyer's suggestion that the slight divergences between theoretical and actual atomic weights in the periodic system may be due to the imprisonment of a quantity of the ether within matter; as just suggested, these differences are more likely due to electronic losses.

If the new theory of mass is accepted we must postulate a quantity of energy in the ether in keeping with its weight. We shall know more about this when these quantities have been calculated by different indirect methods and the results compared. We shall have occasion, a little later, to discuss the temperature of space between which and its internal energy and mass some relation may exist. Heat is usually considered to be due to atomic agitation; we are now assuming mass to be due, possibly, to corpuscular agitation, which already produces, as we know, light and other electro-magnetic phenomena. The day may come when, able to control the internal forces of the atom and effect transmutations, man may set about destroying matter, as such, altogether, for use in his industries at so much per kilowatt-hour. To the peculiar forms of insanity which induce some men to sell eternal salvation and others to capitalize the future, will be added the new feature of utilitarianism of annihilating the earth in order to improve it as a place of habitation.

Chemical Theory of the Ether

Returning to the ether, we find ourselves in better position to discuss its probable nature, and the first theory to be examined, while perhaps the least satisfactory, merits respectful consideration as coming from such an authority as the late Professor Mendeleef, who gave its full development to the periodic system of Newlands, with its strong argument for a common origin of all the chemical elements. Mendeleef's theory is known as the chemical theory of the ether. He suggests that space is filled with chemically inert gases such as argon, krypton, neon and xenon; thus, no chemical reactions would be possible in space, although it is filled with what is actually matter. This is a return to the Cartesian theory of matter filling all space, and implies an atomic structure of the ether. From a purely structural point of view, Mendeleef's theory is not incompatible with the theory of an ether entirely made up of corpuscles, but on account of the larger size of atoms it would be more definitely granular, and therefore less continuous. Cauchy has attempted to calculate the probable dimensions of ether particles and claimed one ten-thousandth of a wave-length as a result. This is not an encouraging figure for the chemical theory, as it is very much smaller than any of the atoms known to us, and it is worth while on that account to examine some of the physical conditions of the medium in space.

This medium is, according to the figures of reliable investigators, under considerable pressure, and Professor Poynting tells us that interstellar space is at a temperature of about 10° abs., or several degrees warmer than the lowest which Sir James Dewar has been able to obtain by artificial means. This would be, of course, an average temperature, because variations must exist in different parts of space. The high pressure combined with low temperature is not in itself suggestive of the presence of known gases.

There is no indication that a fall of temperature lessens chemical activity—in certain cases it has been found to increase it—nor that it in any way accelerates the disintegration of atoms, and there is no reason, therefore, to believe that gaseous activity would be reduced in space by the absolute, or almost absolute, withdrawal of heat. This statement may appear to contradict a previous statement that heat was the result of molecular agitation, but it does not, for gaseous activity, which causes expansion, is an intrinsic activity entirely independent of, though influenced in degree by, the superadded activity imparted to masses or aggregates of gaseous atoms or molecules by heat waves passing through them. Furthermore, no extrapolation of results actually obtained warrants us in suspecting that molecular aggregates can not exist at zero absolute; thus we may well believe that chemical affinity, while influenced by temperature, is in no way dependent on it, but is an intrinsic property of the atoms themselves. Gaseous matter in space is not necessarily "frozen to death."

It has just been stated that there was no indication that a fall in temperature hastened atomic disintegration; the reverse may be true. Jean Becquerel has recently shown that at the temperature of liquid air the transparency of matter increases and the spectral absorption bands become finer. It is well known that the very opposite is the case with a rise in temperature above normal. In this we may see a vindication of the theory that heat is due to molecular agitation, or, to speak more correctly, is manifested as molecular agitation, which interferes with translucent properties.

Phenomena of Interstellar Space

If the ether is a mass of elementary gas or gases, in what relation will it stand to the energies which it transmits? If the ether is gaseous, *i. e.,* material, all our accumulated knowledge of matter is at variance with the accepted facts of astrophysics. If this gaseous ether is the ultimate condition of matter, the luminiferous medium, all our accumulated knowledge of the ether is opposed to many accepted facts of science. The acceptance of a material ether necessitates too much work of reconciliation and the distortion of established facts to suit its requirements. We turn, therefore, to sub-material theories.

The ether transmits but does not manifest heat, light and other forms of energy. Light is not manifested in space—at least not to any appreciable extent; the variations in our distance from the sun do not produce color phenomena of the order of those which a variation in the depth of atmosphere through which we view the sun produces. Heat stands in the same relation to the ether as sound does to gases of suitable density; it is not *manifested* in a non-material ether; it is *transmitted,* and that part of space through which it passes is unaffected. If a molecular mass, our globe and its atmosphere, for instance, be interposed, the light and heat will be manifested, dissipated and finally absorbed by atoms or atomic aggregates, the periods of whose vibrations coincide with theirs. If not manifested they can not be dissipated, but will travel forever in a right line.

But if this is correct, how is it that interstellar space possesses any temperature at all? Why is it not at zero absolute? Heat, as already stated, is known to us by its manifestation; it is manifested in matter and ultimate corpuscles can only transmit it without retaining it. Heat and light may be identical in nature, but they are distinct in their action; it has recently been shown that the change of period in the movement of electrons which absorb light is quite independent of temperature, thus confirming the theory that heat does not affect the corpuscle as it does the atom, and that therefore space, if it were corpuscular (sub-atomic) in composition, could not possess temperature.

Assuming that Poynting's calculation of the temperature of space is right, or even adopting that of 1.5° Centigrade absolute, as was more recently calculated by Schaeberle, we shall either have to accept a material theory of the ether, like Mendeleef's, or else suppose that molecular dusts—solid, liquid or more likely gaseous—are present in space, as material impurities in a sub-material medium. Such a supposition, recently made by the author,[2] is not only possible, but is highly probable. If, as is far from unlikely, this dust is found here and there in masses more dense through which our planet glides, we do not have any further to seek for another explanation of the *aurora borealis* and kindred phenomena, which would be caused by the electrification of this dust when near the earth. These auroras occur at irregular times, whereas the theory of Arrhenius, which attributes them to cathodic rays emanating from the sun, would lead us to expect a continuous or periodic performance. By adopting Villard's theory of the telluric origin of the cathodic radiations of the phenomenon, we can introduce the cosmic dust as a rarefied gas in which it is displayed. Zodiacal light will be due to dusts burning when contacting with our atmosphere, just as on a large scale and detachedly, meteorites will illuminate the sky. Night brightness, as for instance the "extraordinary lightness of whole nights in the year 1831, during which small print might be read in the latitude of Italy and the north of Germany," mentioned by von Humboldt, might have been due to a very dusty condition of space following solar activity. Abney has claimed that the region of space which we are traversing contains benzene vapor, ethyl hydride and other alcohol derivatives; these would assuredly burn when in frictional contact with the atmosphere. The more recent suggestion of a permanent corona around the earth which becomes visible under certain conditions as sky lightning does not stand analysis, but such a corona will exist as the earth passes through dusty regions in space.

If the sun, out of those vast cavities in the photosphere which are called sun-spots, belches forth this cosmic dust, undoubtedly gaseous in at least its early constitution, and the earth gravitates through it, the electro-meteorological disturbances which are observed one week or so after the appearance of spots would be, in a general way, fairly well accounted for. It is significant that the growth of the red flames which has been estimated about 200 miles a second corresponds to a period of about six days to bridge the distance between the sun and the earth's orbit. It is to be expected that this planet be influenced by a material

[2] *Science*, Nov. 20, 1908, p. 728.

bridge between it and the sun. Sun-spots are regarded by many astronomers as a falling-in of a portion of the photosphere, but the reasons for this belief are not conclusive, and it is legitimate to believe in a movement in the opposite direction due to an explosive force within the effulgent crust which, as in the case of volcanoes, occasionally relieves the tension beneath that crust or in its cavities. Our periods of greatest heat often follow sun-spot activity—not that sun-spots are hotter than the rest of the sun's surface, but the matter which is sent forth intercepts and stores heat before it can pass beyond the limits of our orbit to be absorbed by extraneous systems.

A last consideration which makes the chemical theory of the ether untenable is the fact that if space were filled with gases, the temperature near heated bodies like the sun would be very great, and powerful currents would be set up which would be detected by optical if not by other means. A material ether would possess some degree of viscosity and would necessarily interfere with the progress of bodies, and this negative acceleration would create heat of friction, dissipated but undestroyed. This leads us to the consideration of the physical requisites of an ether in which matter, as we know it, must "fit," before we examine any of the other theories which have been offered within recent years.

Failure of Material Conceptions of the Ether

All the experience which has been acquired through telescope, microscope and spectroscope, with and without the aid of the camera, leads to the belief that the all-pervading medium must be uniform and homogeneous. While this may be taken for granted, it by no means implies that the medium must be continuous; in other words, each of its components does not necessarily have to stand in any physical relation to its neighbors, for this would imply a force of affinity or of cohesion which one may be unwilling to grant, as it yields a purely material conception and carries one back to the chemical theory, which has been laid to one side for the present.

Some of the most eminent physicists have adopted the view that the universal medium must be solid; this belief is based on the manner of propagation of light and other high-frequency energies, which take place without appreciable dispersion in space. But, on the other hand, in all theories but one, this medium is expected to be of a nature which will offer little or no resistance to bodies moving through it. At first sight it is hard to reconcile this requirement with the nature of a perfect elastic solid such as we picture to ourselves. It has been suggested that the medium must be somewhat like pitch which shows no track of a body which has passed through it, and we are asked to conceive our planet—not to mention our humble selves—moving at a rate of eighteen miles per second through it, and, what is still more incredible, that this takes place without practically any friction. The truth of the matter is that whether we call it a perfect gas, an incompressible fluid, a jelly, or a solid possessing perfect elasticity, we are tying ourselves down to a material ether, and the acceptance of any one of these conceptions ends in a *reductio ad absurdum.*

As for dispersion, if it be assumed that light is given forth from the entire surface of the sun equally in all directions, the lateral pressure of dispersion at each spherical zone, and at any distance—if it exists—would be equal, and there would be perfect equilibrium between adjacent cones of light; the bases of these cones are equipotential surfaces and no lateral dispersion could be rationally admitted. When, however, the light waves strike an object such as the earth, a shadow is formed. Leaving out the refraction in our mantling atmosphere to which we owe our twilights, the shadow which the earth casts is practically absolute for at least the distance from the earth to the moon (240,000 miles); and it is therefore evident that the medium itself is of such a nature that it will transmit transversal vibrations without any appreciable dispersion. If dispersion in space were serious the light of the stars would be shown as a haze and not as individual points,

The theory of a solid or, to speak more accurately, a rigid ether does not, as we shall see later, appear to be a necessity, and it presents the great weakness of compelling us to rack our common-sense to try and explain the passage of bodies through it, from the lightest comet to the most massive star. Rigidity of rotation was first proposed by McCullagh and its nature will be considered more fully when the subject of vortex-atoms is reached, but, however plausible it may be for material atoms—and it is eminently so—it seems to be a superfluous hypothesis for a non-atomic ether. Rigidity and elasticity of rotation can be compared to the gyroscope which resists deflection and yields elastically, although it is not itself elastic, nor immersed in a medium which could be considered elastic when the gyroscope is at rest. This is an elasticity of motion, not of matter; it must, however, be remembered that, as Lord Kelvin has pointed out, elasticity itself may be but another mode of motion. With elasticity of rotation, one might have practically a fluid ether possessing high elasticity with its oscillatory power, instead of the viscosity of ordinary fluids, with its dispersive quality.

Perfect elasticity by no means implies a solid or semi-solid state; an atomic structure presents elasticity of volume, but equilibrium in a homogeneous, non-continuous medium, regardless of the spaces which may exist between the component incompressible corpuscles, will supply rigidity and elasticity of shape. Pressure in space does not imply elasticity. If elasticity is a rotational effect and pressure one of bombardment, they are not necessarily interdependent. The fact that there may be pressure in space brings one back to the consideration of a gaseous ether, but can not pressure exist in a corpuscular medium, and may not the pressure be a manifestation of the innumerable energies which continually pulsate through space? If all forces—including chemical forces—were suddenly removed from a certain point in space, there could be no activity and therefore no pressure. Pressure is the result of activity, of bombardment, and space is truly "alive" with activity, for, as Clerk Maxwell said, energy transmitted must exist for a time in the medium. No wonder, therefore, that it is under pressure, which Sir Oliver Lodge estimates as equivalent to 10^{37} ergs per cubic centimeter.

Before leaving the subject of pressure in space, it may be well to look further into the matter of ethereal activity. The activity of the ether might very well be of a higher order than that of the energies or forces known to us. When we consider that as far as we can discover the hottest stars have the simplest spectra, it may well be suggested that gravitation, electricity and light may represent falls of potential and not rises from the inherent activity of the ether, which, calculated to secure the necessary rigidity in the theory of vortical motion, is of stupendous magnitude. This degradation of the energy of the universe of ether into the energies known to us is in the same line of development as the degradation of matter, and the laws regulating the conceivable may logically govern the inconceivable.

No *material* conception of the ether is therefore to be considered excepting one which, at first sight, appears perfectly paradoxical, of an elastic solid of a density of 10^{12} (Lodge), as rigid perhaps as steel, and, in that case, fifty thousand times less dense than hydrogen (Michelson).

The Creation of Atoms

If, as already stated, energy, as we know it, is originated in matter—though not by it—and transmitted through a medium the ultimate particles of which are very much smaller than and different in nature from the atoms of matter, the disturbance at the source of origin must be transmitted by a number of corpuscles of that medium and propagated as a bundle of vibrations several corpuscles in diameter. This bundle of lines of force may be called a tube of force; this tube of force may be of any shape whatsoever, depending on the shape of the source of origin and the nature of its disturbance.

Plateau has shown that a liquid cylinder of excessive length and *with a free surface* first assumes an undulating contour, and then breaks up into separate vibrating drops. The resistance of the medium apparently puts the stream into vibration which causes a separation into equal drops by periodic strains which finally overcome the surface tension. The researches of Bjerknes confirmed Plateau's experiment and he found that the distance required for the breaking into drops depended, as might be expected, on the relative densities of the liquid and of the medium. Savart had shown that this natural tendency of liquid columns to break into drops can be induced by a musical note which synchronizes with the period of the drops.

We can now build what is possibly a wild theory, by means of that dangerous tool of philosophy: analogy. Let us imagine a bundle of energy not having a free surface but forming part of a general spherical disturbance, striking an object having an aperture which does not absorb or reflect the energy and therefore acts as a diaphragm; suppose that a cylindrical pencil is thus formed and propagated beyond the obstacle; this tube of force will have free surfaces; the analogy with the behavior of liquids dictates that after a while the tube will resolve itself into spherical drops and these drops we shall call atoms. We have thus created atoms from corpuscles and the energy traversing them; we have given an origin to what Crookes has called an "atomic fog," which is, according to the nebular hypothesis, the basis of the material universe. The "atomizing" of a liquid and the shredding of lead (lead-wool) by an air blast are identical in principle.

But the hypothetical diaphragm can be used to produce quite a different atom from the spherical drops which have just been created, provided the vibration be brought about *before* the energy, corpuscles, electrons, or whatever we wish to consider them, are ejected beyond the diaphragm. If a box with a hole (diaphragm) in it is filled with smoke and the side opposite to the hole is given a short tap causing the smoke to vibrate, a ring of smoke, a vortex ring, will be emitted, with the appearance and general properties of which we are well acquainted. A continuous motion of the smoke will not produce a ring; it will produce a stream, with a skin resistance like the stream of smoke in a chimney; to produce a vortex ring, a pulsation is required which will emit small disks of smoke which can be thinned at the center to the point of rupture by the resistance on the edges of the hole. If, therefore, a tube of force pulsates or is caused to pulsate by an elastic or pulsating resistance or otherwise, when it strikes the diaphragm in the obstacle, a vortex atom will be produced in place of a spherical atom. We have thus created the vortex atom as first proposed by Helmholtz and developed by Lord Kelvin into a theory which has stood the most careful mathematical scrutiny.

That an obstacle in the path of a stream of energy will alter that energy is evident. The conversion of cathodic rays into X-rays shows what impact may do. The clash of two similar or dissimilar streams of energy might create spherical or vortical atoms and the relative speeds and the angle of impact would influence their period of vibration.

The radiation from disintegrating matter on this planet may go far out into space to re-create atoms for use in some other system. The sun, while emitting an enormous amount of energy, may be gathering an equal amount and be a vast atom-factory. Vico with his "metaphysical points" and Boscovich with his theory of centers of force for atoms were the forerunners of the theory that matter is energy objectified, a theory so startling that it would be unwise, not to say positively indecent, for modern science to accept it offhand without at least a show of suspicion. Anaxagoras saw in the energy of atoms the evidences of mental power; even the most sceptic must refrain from criticizing or judging the statement that the energy of the atom is entitled to be called intelligent in the broad sense. It is quite significant that protoplasm molecules are very rich in atoms, each molecule of human hœmoglobin containing not less than 1897.

The Vortex Atom

But we must now return to the vortex atom. It is a gratuitous supposition, all too widely accepted, that atoms must necessarily be round. Secchi favored a round revolving atom. Lord Kelvin and many others found that the vortex atom more completely satisfies the requirements of observed facts, but that the vortex atoms may vary in their shape and proportionate dimensions. It may be best to give Professor Tait's definition of Kelvin's vortex atom, instead of attempting to fashion a new one. "The rotating part of an inert perfect fluid, whose motion is absolutely *continuous,* which fills all space, but which is, when not rotating, absolutely unperceived by our senses." By "perfect fluid" is meant one which is frictionless, clearly an impossibility for matter in the liquid state.

The most pronounced features of the vortex atom as compared with other conceptions which have been offered are its elasticity and its permanent character; its mathematical study is of unusual difficulty, but the properties which it must necessarily possess coincide in a remarkable degree with the observed properties of atoms. The vortex ring, one made of smoke, for instance, can not be cut; it will move away from the edge of the knife; it can, however, be deformed and will vibrate in various ways. It can revolve axially or in any other direction. It is even conceivable that vortex atoms be linked so that a great variety of arrangements would be possible, corresponding to stereochemical groupings.

One more point must be touched upon. Is the ether stagnant or in motion? At first it may appear as rather a waste of energy to attempt to discover if the ether is in motion, but Professor Larmor has shown mathematically that the absence of any optical influence of the earth's motion on light from the sun and stars suggests that the ether moves along with the earth. From another source comes the idea that the earth, being a magnet, drags the ether with it. In what a complicated turmoil the universe of ether would have to be if this conclusion were applied to all bodies in space! This dilemma brings us to the one theory which seems to clear up the most stirring mysteries of astrophysical science.

Reynolds's Theory of the Universe

The theory of the universe, which may perhaps be called the "dark horse," is due to the late Professor Osborne Reynolds, a thinker and mathematican of no mean caliber. The theory is thoroughly discussed and elaborated in his "Sub-mechanics of the Universe," which he very appropriately calls an "inversion of ideas." Instead of considering atoms as comparatively massive particles in a vacuum, a gas or a fluid, he considers them as *negative* inequalities or comparative vacua immersed in the perfectly rigid plenum which the phenomena of the universe require. The atoms in the ether might, therefore, be compared mentally to the pockets or bubbles of liquid in a colloidal emulsion. It is, of course, unthinkable that atoms be perfect vacua, that matter be the expression of nothingness; what is meant is that the ether is perfect fullness and that atoms are infinitesimal spheres of activity containing less ether; mass being a function of activity, there is no connection between quantity of ether and weight. It was with Reynolds's theory in mind that the statement was made that matter and the forces which make it known to our senses might possibly represent degradations of the inherent energy of the ether. The degradation of an element means at once loss of electrons and loss of mass; hence, perhaps increase of ether content or increase of *inactive* corpuscles, or even, which would amount to the same thing, loss of energy to corpuscles outside the atom. All this does not, however, solve the difficulty, it merely inverts the ratios of mass; to complete the system, a theory of the propagation or conduction of matter, in place of its transportation or convection, is necessary.

The Conduction of Matter

In the early days, astronomers found difficulty in ridding themselves of the geocentric idea, and in the same way it must be a difficult thing for the physicist to abandon the idea of positive matter; this conservatism is the fly-wheel of progress. Much harder still should it be to introduce the notion that matter is propagated like waves, like moving pictures on the cinematograph screen which truly live and give rise to emotions, although made up of nothing more tangible than lights and shadows. What a reversal of mental habits to conceive that the centers of force alone move and the component electrons change continually as the waves progress through the compact universe of ethereal corpuscles!

That such a propagation should take place without friction is possible, if friction is purely *intermolecular* and not an atomic operation like non-radiant heat. Heat, as already stated, is due to molecular agitation and all matter possessing heat above absolute zero is undergoing that particular form of molecular agitation; if the period of agitation is greatly increased by heating an article or greatly reduced by immersing it in liquid air, the effect on the hand at normal temperature will be much the same, physically, in either case; it is as if it were applied to a revolving emery wheel. The difference of period between the agitation of the molecules of the hand and that of the substance, whether positive or negative, will result in damage, the organic molecules being unable to respond without destructive decomposition to the periodicity with which they are put in contact.

If atoms can not vibrate in the order of heat or friction waves, any more than the optic nerve can vibrate in the order of sound waves, there can be no friction in the propagation of matter as postulated. Even if friction were interatomic, there would not necessarily be friction between atoms and sub-atoms. If there is any loss from the passage of atoms through space, it can not be as heat, unless the ether be atomic or molecular; it must be more in the nature of optical diffusion and the continual degradation of matter may be the effect of its propagation through space. Electrons may be strewn in the wake of each heavenly body to be swept up by comets in their courses and effect their growth, or gathered some day into nebular clouds from which new worlds will originate to take the place of those which wasted away in ages past.

The theory of the propagation or conduction of matter is equal mathematically to the ether moving with the earth. There is no actual relative displacement of the constituent corpuscles and it was therefore to be expected that, in the light of Reynolds's theory, Professor Michelson's elaborate experiment would fail to show aberration due to motion through the ether.

Man is a mass of prejudice; he is limited to one set of standards. From the first development of his organism from a zoophite, his senses have evolved in relation to matter alone, and it is only within recent times that he has commenced his evolution towards the understanding of submaterial truths. It may be untold ages before he may strike the endless path leading to the answer of the one and only problem in which he is interested and towards which he strives by the study of nature: the mystery of his self-consciousness.

The helplessness of the human mind in presence of the underlying facts of science is the deepest argument for a faith in some inconceivable universal mind of which our own is, at the very best, but an imperfect reflection.

THE VIENNA INSTITUTION FOR EXPERIMENTAL BIOLOGY[1]

BY PROFESSOR CHARLES LINCOLN EDWARDS

COINCIDENT with the founding of our own government, the Emperor Joseph II., of Austria, opened to the public the Prater, the largest park in Vienna. At the entrance is the Prater-Stern, a street-car center directly accessible from all parts of the inner city and the outer districts by means of the city railway and many lines of electric cars. Here the people flock, especially on Sundays and holidays, to that part known as the Volks-Prater, which is a veritable Austrian Coney Island, with music, theaters, a giant wheel, circus, race-tracks, exhibits of natives from various lands and the attractive sights of "Venice in Vienna." On Easter Monday and May Day the largest and gayest throngs seek the Prater, where they visit the many forms of amusement, or walk and drive for miles through the park. Under the four rows of chestnut trees in the Haupt-allée the fashionable aristocrats parade in their fine equipages drawn by beautiful horses and bearing liveried coachmen and footmen.

The International Exhibition of 1873, located in the Prater, had an imposing aquarium constructed after plans by Brehm. More recently this structure has been used by the Zoological Society of Vienna as a vivarium for the display of the smaller animals. In consequence of the existence of an older zoological garden, the royal menagerie at Schönbrunn, it has not been possible to maintain this similar enterprise in Vienna. Following a suggestion of Professor Hatschek, Dr. Hans Przibram obtained the vivarium building from the zoological society in 1902 and joined with the botanists, Dr. Wilhelm Figdor and Leopold v. Portheim, in the establishment of an institution exclusively for scientific research which has already become renowned. The field is not limited, but offers an opportunity for the investigation of any biological problem, chiefly by means of experimentation, upon either plants or animals of the sea or the fresh waters, of the air, or the land, or dwelling in caves or burrows beneath the surface of the soil. The grounds, forming the garden around the vivarium building, were rented from the government for fifteen years. The main building (Fig. 1) had to be completely reconstructed and was then supplemented by two glass

[1] For his courtesy in lending me the photographs here reproduced and for his paper entitled "Die biologische Versuchsanstalt in Wien," *Zeitschrift f. biol. Technik u. Methodik*, 1910, I am especially indebted to Dr. Hans Przibram.

houses and various workshops and cages for the larger animals. The garden is screened from the passing throng by a vine-covered fence and a row of leafy shrubs and trees. As one enters the hall of the institution, he sees, on every hand, the preparations and specimens resulting from the experimental work so successfully carried on here. In the middle of the building are five parallel corridors, while to either side and in the rear are suites of rooms for manifold purposes.

The Vienna Institution for Experimental Biology includes zoological, botanical and physico-chemical sections. By virtue of an agree-

FIG. 1. FRONT VIEW OF THE VIENNA INSTITUTION FOR EXPERIMENTAL BIOLOGY.

ment with the royal Austrian ministry of education the state assists the founders by maintaining two laboratory places in each of the zoological and botanical sections. The award of these tables, as well as the promotion of the general interests of the institution and its close affiliation with the university institutes, is vested in a board of curators consisting of the four professors of the biological subjects in the philosophical faculty of the University of Vienna. Thus far these curators have been Professors Wiesner, in botany (chairman), Grobben and Hatschek, in investigation of the fresh waters of Austria, which thus far has been established for the physico-chemical section which was organized in 1907, and this place is filled by the professors of the medical faculty. The ministry of agriculture has made an annual appropriation for the zoology, and v. Wettstein, in botany. A governmental table has been used for botanical researches under the direction of Professor v. Wettstein. The tables are free to students working under the supervision of the directors, but independent investigators pay an annual fee of 1,000 crowns. About fifty workers are here engaged in investigations each

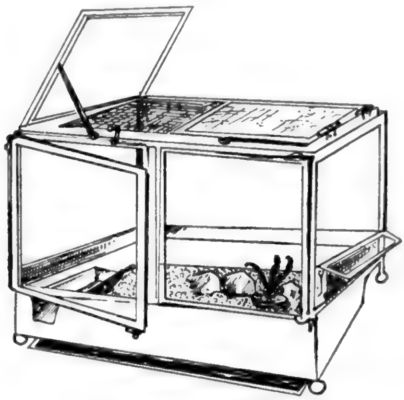


FIG. 2. TERRARIUM.

year. At present the staff of the institution is as follows: zoological section, director, Dr. Przibram, assistants, Drs. Kammerer and Megušar; botanical section, directors, Dr. Figdor and Ritter v. Port-

FIG. 3. OUTDOOR TERRARIA.

heim, assistants, Herr Fröschel and Herr Freund; physico-chemical section, director, Professor Pauli, assistant, Herr Schorr; fresh-water investigations, Herr Brunnthaler.

The Vienna institution differs from most of the preceding biological institutes in that here experimentation, carried on for long periods of time, even generation after generation, if necessary, and always under the best possible conditions, takes the place of research in descriptive and comparative anatomy, or the briefer experiments of physiology. In the study of experimental evolution one not only follows the organisms through ovulation, fertilization and embryogenesis, but the new generation must be raised to the adult stage for another breeding. The laws through which the external factors of existence influence the vitality can only be determined when it is possible for the organisms

FIG. 4. HOUSE FOR HIGHER VERTEBRATES.

experimented on to live under unchanging conditions for months or even years. Darwin acted upon these principles and his garden at Down must always rank as one of the greatest laboratories for experimental biology. It is only necessary to visit the zoological institute in Würzburg with its vivaria, series of basins and shaded pond, to realize, as one can from his writings, that Semper also was fully aware of the primary importance of experimentation in the solution of biological problems. Along with the foundation and growth of the Vienna institution has been that of the station for experimental evolution of the Carnegie Institution created and directed by Davenport, and the gardens developed by Ewart and Bateson in Great Britain. Similar establishments for the study of genetics have been advocated by Behla (1894), and more recently by Plate (1906) and Müller (1907). Indeed, every biological laboratory is more or less permeated by this spirit of experimental investigation which the recent literature of biology shows may be successfully carried on even without elaborate equipment.

In keeping animals in confinement it is necessary not only to know their habitats, but also their manner of movement and whether they prefer light or darkness and living or dead food. For the investigations upon land animals carried on in the Vienna station, terraria have been constructed with especial care. The sloping bottom of the metal terrarium (Fig. 2) contains soil, with drainage for superfluous water and micro gas burners, or electric bulbs for heating. On one side of the

Fig. 5. View of the Glass House for Low Temperatures.

glazed superstructure and in the roof, ventilating screens are inserted. According to the degree of moisture needed the ground material varies from bran for meal-beetles and clothes-moths, sawdust for cockroaches, clay for bees, wasps and tiger-beetles, fine sand for leaf insects and rove-beetles and common garden soil for earthworms, glow-worms and wood-lice. Plants are used for the production of oxygen and food and with pieces of old bark and branches constitute a natural environment with its grateful shade and hiding places. To provide necessary moisture the ground is sprinkled in the early morning and during the day for the diurnal animals and in the evening for the nocturnal forms. Each day an artificial mist, or rain, is produced in the terrarium atmosphere by means of a hand atomizer or a small compression air pump.

Meal-worms constitute the most useful general food. These larvæ are placed in small, oval, porcelain sugar-bowls which because of their concave sides, prevent escape. For different animals it is necessary to provide scraped meat, fresh ant pupæ, earthworms, snails, flies, kitchen scraps, chopped fruit and vegetables, as well as any small animals available. Careful attention is given to cleaning the cages. The water basins are emptied by siphons and then sponged. The plants in pots and tufts of moss and turf are changed, stones and wood scoured with hot water and the upper layer of sand or earth renewed. Smaller vivaria are employed for special experiments. In these a double cover

FIG. 6. INTERIOR OF THE GLASS HOUSE FOR LOW TEMPERATURES.

of gauze provides an air space to ensure the circulation of air. The nests of social insects, like bumble bees and burrowing wasps, are transferred from their natural locations in the late evening when all of the family are at home. The insectaria are then placed in moss-covered ditches, or else buried in the earth, and in a few days the insects become quite contented.

In order to mitigate the conditions of confinement which unfavorably affect certain animals there are four large and many small outdoor terraria (Fig. 3).

There is a separate house (Fig. 4), bowed around the north side of the grounds, for heredity researches upon the higher vertebrates. Each of the sixteen cages has an outwardly-sloping cement floor, wire screen ventilators, heating pipes and electric lights, and opens into a garden plot having trees for the cats to climb in, basins in which swimming birds may disport themselves and soil surrounded with cement walls within which the wild rabbits may burrow. The kangaroos here find ample space in which to run about while snakes and lizards sun themselves on the rock-piles and turtles and frogs alternate between land and water.

The two glass houses (Fig. 5), one adapted for warmth and the other for cold, are in the south portion of the grounds. The glazed superstructure rests upon a thick wall and the floor lies one half a meter below the ground level. Each glass house is divided into a cul-

FIG. 7. MIDDLE CORRIDOR OF THE MAIN BUILDING WITH CULTURES OF ALGÆ.

ture room and a preparation room (Fig. 6), the latter being connected with the main building by a glass-covered passage-way. Each culture room is provided with a water and sand bed and a water reservoir sunken in the floor. Electric light enables the experimenter to work continuously when necessary. Venetian curtains are used as a protection from excess of light or cold.

The middle corridor of the main building is covered with a double glass roof. One portion, used as a warm room, contains sweating boxes maintained at various temperatures. In the cold portion (Fig. 7) the conditions are favorable for the culture of fresh water and marine algæ and the various organisms that grow in slime. The garden includes beds for the cultivation of plants for fodder and the experimental work. One large basin (Fig. 8), and four that are smaller, contain the higher water plants and algæ which grow during the warm season. In the shady, western part of the garden there are six cement basins (Fig. 9), especially for the rearing of plants, and at the same time serving as a home for the hosts of protozoa that wander in and can be used for investigations.

A station for experimental biology must have not only the proper equipment for breeding and rearing organisms under natural conditions, but also for artificially changing and controlling the external factors of the environment. The physico-chemical laboratory (Fig. 10) provides the substances used as variable external factors and also to determine the physico-chemical properties of the biologically important colloids.

FIG. 8. LARGE BASIN IN FRONT OF THE HOUSE FOR HIGHER VERTEBRATES.

These albuminous substances are placed in parchment paper sacks, in closed vessels or in moving water from which the carbon dioxid has been removed and thus for weeks and months are kept free from decay or carbon dioxid or other noxiousness of the laboratory air. A heliostat provides for the penetration of objects with the rays of sunlight and for the ultra-microscopic ends. A nephelometer is used for the estimation of cloudiness whereby errors in physiological observation due to the confounding of comparative and observation fluidities may be reduced. A dilatometer serves to determine the changes in volume and variations in water content of the biocolloids. Then there are pycnometers of all kinds for specific gravity computations and an Ostwald's viscosimeter, in a transparent thermostat, for the determination of the viscosity of colloid solutions. Especial value is placed upon electrical methods of investigating colloids. A proper distillation plant serves exclusively for providing the purest so-called conducting water. There is an apparatus after Kohlrausch with various electrode vessels for the estimation of the electric conductivity of electrolytes. For the determination of ion concentration in solutions there is a complete contrivance made of brass with electromotor power and having concentration chains with an elongated measuring bridge and a mirror galvanometer with reading telescope. The mechanisms for the calculation of the electric charge of colloids are technically perfected. The conducting apparatus of Landsteiner and Pauli was tested in an investigation

FIG. 9. CEMENT BASINS IN THE GARDEN.

on toxins. Here each colloid, separated from the remaining fluid by the electric permeation, arises and can be easily isolated and tested. Since only the alternating current is found in the institution, two batteries, one of 200 and one of 75 volts, are employed to produce the current. In addition there are the necessary normal and precision thermometers, the instruments for the determination of the freezing point and the coagulation point, precision rheostats, Weston's volt- and ampere-meter, polarimeters and numerous small auxiliary apparatus.

The large general laboratory has fifteen working places fitted with all the usual optical and histological apparatus and reagents. The necessary conditions for the study of the influence of mechanical agencies are enough light, as little dust and infectious material as possible and sterilizing flames. One line of research is to subject organisms to the influence of different densities in the surrounding medium. For fluids there are basins containing different concentrations of salts, brackish water, etc., with an areometer for measuring the specific gravity of each of the various liquids. For gases there are hand air pumps and means of attachment to the supply pipes of the large electric air-pump located in the cellar. For changing the normal influence of gravitation there are clinostats regulated by clockwork and centrifuges with contact plugs for tapping the electric power wherever needed.

Two dark rooms (Fig. 11) are fitted for studying the influence of light. Both open into a dark corridor from which a triangular door

FIG. 10. THE PHYSICO-CHEMICAL LABORATORY.

leads into an anteroom lighted by a red dark-room light. The larger dark room serves for investigations upon the influence of definitely determined lights. Hung up at one end is an arc lamp in which different colored carbons can be used. The elongated form of the room makes possible experiments in which the organisms are placed at different distances from the light source. For investigating the influence of variously colored surroundings, small vivaria are placed in lighted rooms with colored glass covers for direct light, or colored wall coverings, for reflected light. A special apparatus has been constructed for the study of under and over lighting of fishes and amphibia (Fig. 12). For over lighting the aquarium is covered with an enclosing box open above (*o*) and for under lighting the box is closed above (*u*). For increasing the under light there are mirrors (*s*) at an angle of 45° beneath the aquaria. To dispense with these in over lighting a black paper is shoved under the aquarium. Cave animals and fungi are bred and observations made upon etiolated plants and regeneration against the exhalations of various crystals. Through a trap door iron steps descend into a dark vaulted cemented cellar room which is used as a cave. The air is saturated with moisture by water standing on the floor and the temperature is maintained at 12° C.

For all of the purposes of the institution a reliable heating plant is necessary. A central low pressure steam boiler furnishes rather con-

FIG. 11. DARK ROOMS FROM THE CORRIDOR.

stant warmth for the main building, with a warm water system for the glass houses. Small thermostats, which can be exactly regulated, maintain the desired temperature of the different rooms. The northeast half of the building is kept at the ordinary room temperature (17° C.), while the southwest half is warmer and includes seven rooms. In a glazed compartment (Fig. 13) is the highest temperature (37° C.), next the portion of the same room separated by the glass partition (27° C.), then the warm glass house and the warm corridors for terraria and aquaria (20°–25° C.). A large basin is warmed in winter by a tinned tube kept at 10°–12° C.

The Vienna institution for experimental biology is a pioneer in the use of the carbonic-acid cooling machine for maintaining a cold environment so that different plants and animals can be observed during several generations at specified and perfectly controlled temperatures. Four rooms are kept at + 5° C., + 10° C., + 15° C. and + 20° C. The carbonic acid machine (Fig. 14) produces 5,500 calories hourly.

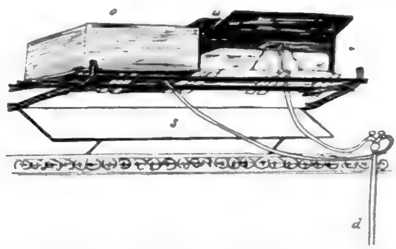


FIG. 12. APPARATUS FOR OVER AND UNDER LIGHTING. *d*, compressed air; *s*, mirror; *o*, box, open above; *p*, box, open below; *w*, glass walls.

The fluid carbonic acid flows into a wrought-iron spiral core within a carefully isolated receptacle made of tin plate. The salt water surrounding the spiral core is cooled to a low temperature by the sudden

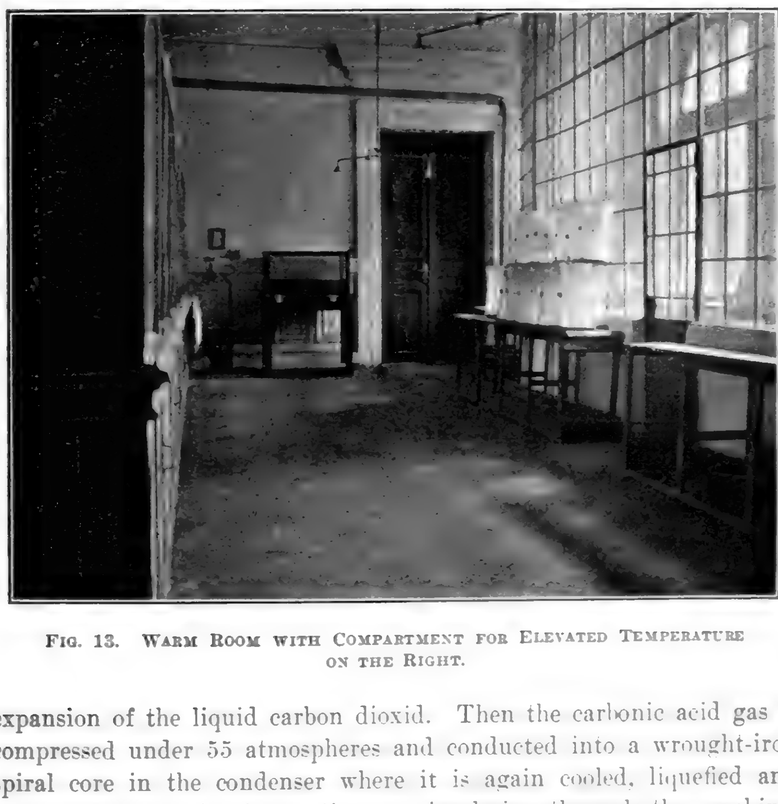
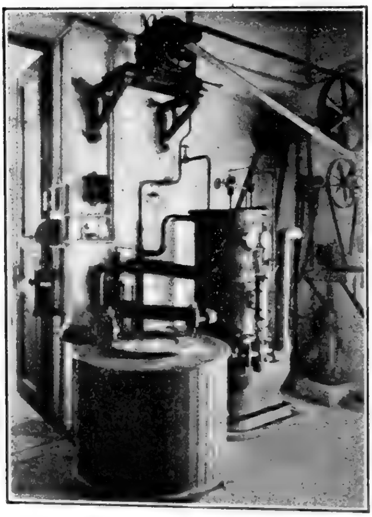


FIG. 13. WARM ROOM WITH COMPARTMENT FOR ELEVATED TEMPERATURE ON THE RIGHT.

expansion of the liquid carbon dioxid. Then the carbonic acid gas is compressed under 55 atmospheres and conducted into a wrought-iron spiral core in the condenser where it is again cooled, liquefied and ready to flow on in the continuous circulation through the machine.

The cold salt water is pumped through the extensive cast-iron radiators of the different cold rooms and the temperature regulators automatically open or shut the valve at the inflow of the cold salt water.

For many years it has been demonstrated, notably in the great Berlin aquarium, that marine animals and plants may be transported a long distance from their native habitats and then live on in aquaria with unimpaired health and growth. Hence it became an essential part of the plan to include marine organisms within the field of work of the institution and a complete equipment was installed for the investigation of problems of marine biology. Natural sea water, from the zoological station in Triest, is brought in car loads of thirty casks, each containing 500 liters. It is not difficult to maintain the proper concentration of salts and the same water can be used for years. It is not more expensive than artificial sea water, which is apt to vary in its constitution. Non-corrosive substances like glass, porcelain, glazed clay, cement, wood, hard rubber and lead lined with tin, were used in the construction of the aquaria for sea water. A plan of these aquaria, with the associated apparatus for aeration (Fig. 15), shows the distribution of sea water from the elevated reservoir (*A*), to cement basins (*D*), or to the smaller isolation jars in the next compartment. The effluent water, after being cleansed by running through the filter (*H*), is stored in the subterranean cistern (*K*), and thence driven by the



A

B

FIG. 14. *A*. CARBONIC-ACID COOLING MACHINE with condenser, pumps for the compression of carbonic acid gas and for the circulation of the cooled salt water.

B. ONE OF THE COLD ROOMS with the cast-iron radiators for the circulation of the cold salt water.

sea-water pump (Fig. 16), up to the reservoir. The air pump (Fig. 16, *Q*), driven by an electric motor, forces air, which may be diluted by the attachment (*P*), or compressed to five atmospheres (*R*), into five tanks holding 455 liters (*T*), from which, by means of a reducing valve (*U*), it is allowed to escape under a pressure of from 1.1 to 1.2 of an atmosphere and is then distributed (*V*) to the aquaria. In the case of delicate animals, or eggs, solitary or in masses, the air must issue from the terminal plug in very fine bubbles. The outflow is through a plug of bamboo, or merely a piece of finely perforated rubber, while for the larger basins, charcoal or pumice is used. A natural plankton and bottom fauna develops, which is of inter-

FIG. 15. PLAN OF THE SEA-WATER AQUARIA AND THE AERATION EQUIPMENT. *A*, reservoir; *B*, outlet pipe; *C*, ebonite cock; *D*, basin; *E*, *F*, removable outlet pipe and plug; *G*, outlet pipe; *H*, filter basin; *K*, cistern; *L*, riser pipe; *M*, pump; *N*, inlet pipe. Aeration Apparatus: *O*, inlet filter; *P*, attachment for air dilution; *Q*, air pump; *R*, attachment for air compression; *S*, manometer; *T*, air reservoir; *U*, reducing valve; *V*, conducting pipes; *W*, outlet; *X*, flexible connection; *Y*, glass tube; *Z*, excurrent perforated plugs.

est as material for investigation and important as food for animals under experimentation. Such forms appear as small hydromedusæ, ctenophores, worms, ascidians and numerous copepods. Much additional food is required and for this chopped fish, or other meat, is used, but given in small quantities to avoid spoiling the water. Tunicates and mollusks like *Nassa* and *Mytilus*, placed in the larger aquaria, quickly remove the food débris. Protection from the sun is necessary to prevent an excess of green algæ from obscuring the subjects of experimentation. In the small covered jars the proper concentration of salts is maintained, after evaporation below the original water level, by regularly adding fresh water from a vessel standing near, so that the temperature will not be altered. The aquarium bottom is varied according to the nature and habitat of the animal being studied. Coarse mussel-shell sand is used for *Amphioxus* and fine slime for marine annelids like *Capitella.* The burrowing animals are protected from direct sunshine. Where the proper bottom is not provided many burrowing animals lose the habit in confinement. Crustaceans are very sensitive to temperatures higher than 22° C. or lower than 6° C. Some kinds of living plants and animals can be transported from the sea simply in moist water-plants. Those of other species must be placed in individual glass containers, each covered with wet parchment paper and packed in a straw basket and all carried in a

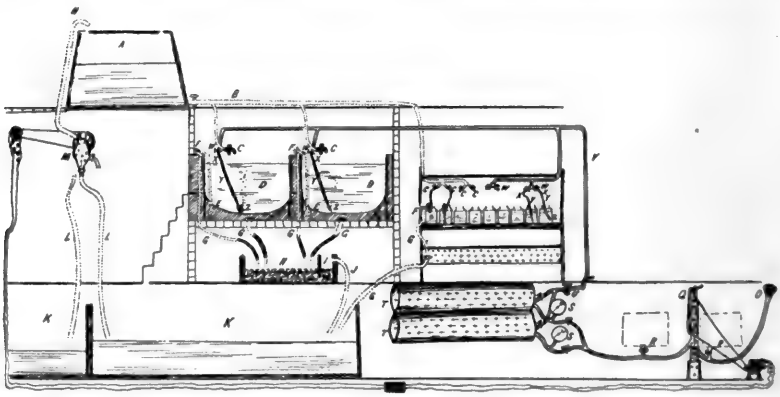


Fig. 16. Pump for the Sea-water Circulation.

large wooden tub. For especially sensitive animals sometimes a steel flask of compressed oxygen, the "hydrobion," is attached to the transport tank. By means of a reducing valve opened at the beginning of the journey, the flow of oxygen is properly regulated. On account of injury in travelling to the apparatus, or to the animals in striking against the outflow tube, it is found more satisfactory to saturate the sea water with oxygen before the journey and so dispense with the "hydrobion."

The aquarial and circulatory system for fresh water is less complicated than that for sea water since it is not so necessary to use the non-corrosive materials in its construction. The water supply, from a height of 2,000 meters, is free from the excess of lime and phosphorus found in the ground water which comes through the Danube alluvium. The rain water, collected in subterranean cisterns, is also used. The more active animals, especially the carnivorous species which chase their prey, require the larger aquaria. An animal 10 cm. long should be allowed a volume of water of 1 dm^3. Carnivorous fishes, crustaceans and aquatic insects must be of about the same size and only a few in each aquarium. To avoid cannibalism the parents must be separated from the eggs, or spawn and the young, except when the parents brood their offspring. Comparatively small vessels are sufficient for indolent forms like tadpoles, salamanders, aquatic insects and most crustaceans. In most cases when breeding, the larger the tank the more certain the result and the more numerous the progeny. Some animals need stagnant slowly flowing water, others a rapid current, some always live in the water, others only during certain times of the year and still others only during certain stages in the life history. Sharp-angled stones are

FIG. 17. MUSEUM OF THE VIENNA INSTITUTION FOR EXPERIMENTAL BIOLOGY.

necessary for certain fishes and amphibia to scrape against in order to remove from their skins such deadly enemies as the fungus *Saprolegnia*. The annual natural range of temperature must be followed, especially in the breeding of animals. Inhabitants of stagnant pools require a range from 4°–35° C., those of slowly flowing, shallow waters 4°–25° C., of the greater depths 4°–18° C., of rushing, rough mountain brooks with shallow places 4°–15° C. and of caves 12°–17° C. Carnivorous animals need be fed only every other day, and because of the restricted movement in confinement overfeeding leads to fatty degeneration, especially of the reproductive organs. If diseases appear the sick animals must be isolated and the aquaria very carefully cleansed with hot water and the use of disinfectants. *Saprolegnia* and other ectoparisites are killed by baths of 5 per cent. potassium permanganate, or a light brown solution of ligno-sulphite and ulcerated wounds are touched with a brush, or wad, soaked with concentrated ligno-sulphite.

In the first museums of natural history abnormalities were collected, but later such specimens were discredited as of no value in the system of biological classification and seldom of interest in phylogeny. However, in recent years developmental mechanics has fixed our attention upon the causes of development and by means of the experimental methods many kinds of malformations have been created at will. We now seek the explanation of abnormalities occurring in nature, pro-

FIG. 18.

duced by "nature experiments," and these monsters and variations again become of value as museum specimens. The results of experimentation carried on in the institution are preserved and exhibited in the museum (Fig. 17), in the form of preparations, photographs and wall charts, and in addition preparations from other experimenters and malformations from nature are being collected. Regarded as of primary importance are the results of experiments concerned with development, regeneration, adaptation, variation in instincts, heredity and species transformation in animals and plants. Of secondary importance are the abnormalities of form and color like supernumerary structures, albino or nigrescent individuals, which have not been produced experimentally, and whose cause is unknown, or at most can only be shown indirectly through analogical deductions. The cases of the museum are located in the entrance hall of the main building and in the adjoining front corridor. Most of the specimens are preserved in fluid, for only a few of the birds and mammals are stuffed and but a minority of the echinoderms and crustaceans are dried. The insects, hermetically sealed in shallow, glass covered cases, represent the influence of temperature upon lepidoptera, of protective resemblance and mimicry, of the series of moultings, of normal growth and growth as influenced by external factors and processes of regeneration, from the egg to the imago. In all cases it is important to have the normal control form exhibited alongside of the experimentally produced variation.

Dr. Przibram publishes a complete list[2] of the animals cultivated in the Vienna institution with important data for each species, concerning the kind of vivarium, or aquarium used, its dimensions and the number of individuals which may there live together, the food, natural habitat and other details, as well as the name of the investigator and publication dealing with each form. The bibliography of papers published by the workers in the institution and Dr. Przibram's summary of these investigations and others being prosecuted furnish an outline of the remarkable scientific productivity resulting from only eight years of research. Such institutions as this of Vienna will do much to solve the great problems of biology. The practise of medical asepsis has permitted operations upon all classes of organisms giving new and valuable data in the field of regeneration. Color has been experimentally investigated as to its nature, whether due to the pigment formation or to the activity of chromatophores, and its relation to light, food, moisture and other external factors as well as its correlation with the animal's vision. By means of the chemical methods of precipitation, agglutination and coagulation, species and hybrids have been tested and the degree of relationship between members of larger groups has been indicated. By the combination of methods of breeding, and subjecting organisms to the influence of changed factors of existence, the laws of heredity will be more clearly established, and the inheritance of functional adaptations acquired under definitely controlled conditions may be demonstrated. The nature of the organ-forming substances in the germ cells and their embryogenesis is being studied. Through physico-chemical methods the biocolloids have become better known and finally the great mystery, the synthesis of living matter itself, may be revealed.

[2] *Zeitschrift f. biol. Technik u. Methodik,* 1910.

THE RELATION OF THE MANUAL ARTS TO HEALTH

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THE relation of the manual arts to health may be considered under two aspects: as they affect the immediate well-being of the pupils and teachers concerned, or in their ultimate influence upon the individual and upon society. Under the former caption belong the hygienic rules pertaining to the performance of the manual occupations in the school, these mostly of negative and precautionary nature The latter relation has to do with the positive contribution which the manual arts are capable of making toward the final attainment of mental and physical health.

Regarding the former, there is probably little to be said that would be new to those who know the manual arts practises from within. The well-trained teachers of this work are aware that the manual arts, inasmuch as they frequently involve "near-work" and sedentary posture, share with other school subjects the danger of injury to eyes, lungs, nervous control and symmetry of form. Teachers of the household arts, for example, appreciate the fact that sewing, in particular, makes demands upon the eyes and the spine of hardly less hygienic import than the much-berated practises of reading and writing. The forward inclination of the head, however occasioned, produces spinal curvature, sub-normal vital capacity and myopia. It is hardly necessary to point out that these dangers are greatly intensified by the use of small models, too fine stitches, dark colored goods, or any materials which, because of a lack of color contrast, make visual discrimination difficult. Professor Schuyten, of Antwerp, investigated the handwork of some four thousand schoolgirls of Belgium and found that about one third testified to visual difficulties in connection with their sewing. Austria has found it necessary to limit by law the fineness of materials which may be used in the manual work of children under ten years of age and to adopt other regulations pertaining to this line of school practise. The German investigators have endeavored to elaborate norms to govern various matters of manual occupations, including posture, delicacy of muscular coordination, kind and amount of light, length of the period of instruction, and its location in the school day.

Teachers of sloyd know that the use of the plane may throw the child into a more unfavorable position than the use of the pen, and that special and unremitting attention is necessary to minimize the dangers of such incorrect postures. Asymmetrical growth can not be avoided except by a frequent change of muscular tension. Tools and materials must not be pressed against the breast. Ventilation is more important in the shop than in the class room. Sand-paper and injurious colorings should be used as little as possible.

Drawing teachers likewise are now fully cognizant that there are hygienic aspects of their work which can not be safely neglected. For example, the necessity of avoiding accuracy of detail as an aim in the lower grades of instruction, the use of sharp-pointed pencils, intricate models, trying color contrasts, poisonous coloring ingredients, cross-lined paper, etc.

Although all the above requirements and others relating to the internal hygiene of the domestic arts are of extremely great importance and suffer frequent neglect, it is the purpose of this paper to point out some of the larger and more positive relations of the manual arts to national health.

The *problem of vitality* underlies almost every social and political situation confronting us. We are becoming acutely conscious of the possibilities of conservation in the line of health and efficiency. Professor Irving Fisher estimates that of the one and one half million deaths occurring annually in the United States at least six hundred and thirty thousand are due to preventable causes. He computes that the economic loss from these postponable deaths is more than one billion dollars every year. Preventable illnesses are still more numerous and are accountable for the waste of almost another billion per year. The running expenses of tuberculosis alone are sufficient to support six hundred Stanford universities, or three fourths of all the common schools in the United States. Typhoid fever robs us of half as much as tuberculosis. Infant mortality, despite all the advances of preventive medicine, has not appreciably decreased in thirty years. In the most civilized countries from fifteen to twenty-five per cent. of the children do not live to the age of one year, mostly because of parental ignorance and the neglect of a few simple hygienic measures. If our present stock of knowledge pertaining to health prophylaxis were made universally effective the average length of human life would be immediately increased by not less than sixteen years. Certain diseases we know are even now on the wane and the spread of some others has been checked, but the ravages of a few seem to derive impetus from the unnatural strains and conditions of civilized life. Among the latter are, first of all, the nervous disorders of insanity, hysteria and neurasthenia, and, until a few decades ago, the two most wide-spread and terrible plagues of recent centuries, tuberculosis and syphilis.

It is not contended that the physical salvation of the nation is to be attained solely through the remedy here offered *i. e.*, the extension and proper teaching of the manual arts. The problem is much too vast to admit of any such simple solution. It must be attacked from a hundred angles. The resources of science, education, politics, religion and art will have to be marshaled to this purpose as they have not yet been. There must be persistent and intelligent effort directed at every opening. No one measure nor any set of measures will suffice, and therefore in presenting the claims of the manual arts for recognition in this work let it be understood that no specific, or panacea, is advocated.

Let us consider, however, the contribution which domestic science is capable of making toward this end, and for our purpose let us conceive of domestic science in the broadest possible sense, including all the internal factors that go to mold the home: household economics, the science and art of preparing food, the hygienic oversight of the domestic appointments, the elements of personal hygiene, and most central of all, the care and instruction of young children. Where else can we find an array of subjects promising so much for the well-being of humanity? The problem of national vitality *is* a politico-social, economic-industrial and medico-educational problem, *but it is first and last a problem of the home.* Tuberculosis is a disease of the *home* rather than of the factory or shop, and can not be eliminated short of a material regeneration of household conditions. Typhoid fever will linger after the purification of all water supplies unless the hygiene of the poorer homes is vastly improved. A quarter million of our babies will continue to die every year regardless of progress in the affairs of government, industry and science, unless prospective parents are liberally educated in this most sacred and most difficult of all human duties.

During all the years of plasticity before the child can be reached directly by society through legal or educational measures it is wholly at the mercy of the home. Perfect nutrition, for example, is the foundation stone of happiness and morality as well as our chief defense against disease; and nutrition is an affair of the home. Malnutrition through the period of childhood permits no complete recovery. Efficiency is more dependent upon food and the hygiene of the digestive tract than upon any other one factor. The child that is permitted to bolt its food at the domestic table is not very likely to profit greatly from school instruction in the virtues of mastication. Not less than five to ten per cent. of all school children suffer from imperfect nutrition. They are the ones who develop most readily into nervous wrecks or fall victims of contagious diseases. The hygiene of the mouth alone is considered by Dr. Osler as important from the standpoint of health as the alcohol question. Many of the most important contagious diseases are ingested through this source. Most mouths will continue to be unspeakably dirty until practises of oral hygiene are made habitual in the home. Ninety to ninety-five per cent. of our school children have one or more defective teeth. The sixth-year molars, as a rule, begin to decay within two years after their appearance. The teeth can only be saved by intelligent attention in the home. An individual's ideals of personal cleanliness are an off-shoot of the semi-instinctive sentiments of disgust and are pretty well molded, once for all, in the years preceding school age.

Again over-stimulation in the early years of childhood will leave its permanent influence upon health and character. A large proportion of parents do not half appreciate the importance of sufficient sleep for children. I have known a four-year-old child to be dragged out to a whist party, there to be kept awake till midnight, and then allowed to drink two cups of strong coffee. Investigations into the hours of sleep of school children show that more than half our school children sleep fewer hours per day than authorities have set as the safe minimum. Innumerable children are kept in a state of semi-intoxication by tea and coffee, drinks which are probably as injurious to the young as beer to the adult. Is it not inevitable that as long as such conditions obtain in the home the legal campaign for temperance will be empty of results, and even the artificial restrictions of vice sorely disappointing? Is it not evident that the first condition of moral development is physical health and perfect emotional balance? Neither the juvenile court, nor the playground, nor ethical instruction in the schools can undo the vicious work of the unfavorable home environment.

All of the above and much besides must be conceived and taught as part of domestic hygiene, which too often has concerned itself exclusively with the externals, such as architecture, plumbing, heating, ventilation, etc. The scope of the subject must be enlarged to include everything having to do with the physical and mental health of the family. In a thousand ways there are intimate and delicate relations of personal hygiene which can be adequately dealt with by no other agency than the home. As an example of this may be mentioned the instruction of children in the functions and hygiene of sex. Society faces few problems more important than this one and, considering the prevailing parental ignorance and neglect, certainly few more difficult ones. Havelock Ellis, after twenty years of scientific investigation of the pathology of sex development, reaches the conclusion that only a small minority of children reach maturity without suffering some of the results of sexual ignorance. The problem is equally one of national health and national morals, as is eloquently but awfully attested by the existence of between one and two million syphilitics in the United States. It is doubtful whether the question of sex hygiene can be satisfactorily solved in this country by instruction on the subject in the public schools, and much is to be said against this solution, but unless the home can be educated to deal more wisely with the situation than it has yet done it will be necessary for us to follow the example of Italy and certain other countries by placing part of this responsibility upon the schools.

For these and many other reasons, a biological view of human progress counsels us to give more heed to matters of domestic and personal hygiene. Under the present conditions of civilization, more than ever before, man's body, mind and morals are being subjected to difficulties which they were not evolved to meet. Among primitive men, morals were natural and easy, intellectual strain was intermittent and of short duration, while the body throve in its natural habitat of fresh air, sunlight and varied muscular activity. The problem of existence reduced itself chiefly to obtaining food and avoidance of becoming food for others. To-day, conditions are quite the reverse. Possessed of the same animal and egoistic instincts so necessary for the very existence of our ancestors we are required to overcome these in the interests of a higher and more difficult moral standard. The complexity of industrial and social life, with its rivalries, competition and absurdly artificial standards of living, has brought the necessity of *continuous* mental and physical exertion. The body has been exiled from its Garden of Eden to the unnatural and unwholesome environment of house, office, factory and mine. The human body is not exempt from the consequences of the biological law that *the existence of an organism is jeopardized whenever it is exposed to conditions widely different from those which directed its evolution.* Fortunately we are not reduced to a choice between extinction, on the one hand, and a return to nature, as advocated by Rousseau, on the other. A diligent application of the laws of personal and social hygiene will preserve us from this dilemma. Nothing else will, and the contribution of domestic science to this end is absolutely essential to its ultimate success.

Almost if not quite as much can be said for that branch of the manual arts technically designated as *manual training.*

Ever since Seguin's classical experiments with manual training in the education of feeble-minded children, nearly three quarters of a century ago, the school has moved rapidly toward a clearer recognition of the close inter-relation between mind and body. For hundreds of years education had been controlled by a bifurcated educational aim, with most of its emphasis on the side of mind. In the last few years, however, the psychologists have learned a great deal about the motor aspects of mental activity. They have demonstrated that almost any simple act of attention involves muscular innervation and, contrariwise, that motor exercise quickens intelligence. Psychology teaches that body and mind have grown up together and that the latter has no *raison d'être* apart from motor adjustment. When educational practise neglects either aspect of the duplex organism with which it deals, the results are bound to be unsatisfactory.

Let us consider more specifically *the contribution of the manual arts to the attainment of perfect mental balance.* Statistics are unanimous that insanity, hysteria and neurasthenia are rapidly increasing in all civilized lands. Now, the newer psychological interpretations of insanity are of the utmost suggestiveness for education. Originally, the insane person was thought to be possessed of devils, cursed of God, etc. Later the scientific studies in neurology led to the theory that insanity in all cases is due to lesions of the brain: to actual degeneration of the nervous tissues induced by hypothetical toxins of disease. This is demonstrably true for certain forms of insanity. But for a very large proportion of insanities and for most, if not all, of that border-line group designated in psychiatry as the *psychasthenias,* the theory of lesions remains absolutely without positive confirmatory evidence. In regard to these the belief is rapidly gaining ground among psychiatrists that we have to do not with diseased tissues in the ordinary sense, but rather with *disturbances of function* which in greater or less degree are amenable to correction by the so-called "method of re-education." This system of therapeutics has already proved successful in numberless cases of *depression, hysteria* and *neurasthenia,* and is believed by America's leading authority on insanity, Dr. Adolph Meyer, to be hardly less applicable to the form of adolescent insanity known as *dementia præcox.* Recent extensions of our knowledge of this disease are so pertinent to our theme as to warrant a brief discussion of it here. *Dementia præcox* is one of the most interesting forms of insanity for three reasons. In the first place, it is extremely common, accounting for some thirty per cent. of the total admissions to insane hospitals. In the second place, it does not prey upon the old or mentally decrepit and is not allied in any way with the diseases of immorality. Instead, it attacks the youth, and not infrequently the youth of most marked intellectual promise. In the third place, some of the newer studies of the disease show that it is due to definite ascertainable *functional* disturbances of the individual's mental evolution and that it will yield to the right kind of educational treatment. As characterized by Dr. Meyer, *dementia præcox* is "a miscarriage of instincts through lack of balance"; a deterioration of habits, "due to progressively faulty modes of meeting difficulties." We are informed further that it is most likely to develop in the youth of the "repressive type," characterized by seclusiveness and what is likely to be taken for "depth of thought." It usually involves fantastic day-dreaming, sexual imagination, brooding over disappointments and (the most central symptom) *a discrepancy between thought and action.* As described by Dr. Meyer:

There develops an insidious tendency to substitute for an efficient way of meeting difficulties a superficial moralizing and self-deception, and an uncanny drift into so many varieties of shallow mysticism and metaphysical ponderings, or into fantastic ideas which can not possibly be put to the test of action. All this is at the expense of really fruitful activity, which tends to appear insignificant to the patient in comparison with what he regards as far loftier achievements. Thus there develops an ever-widening cleavage between mere thought life and the life of actual application such as would bring with it the corrections found in concrete experience. Then under some strain which a normal person would be prepared for, a sufficiently weakened and sensitive individual will react with manifestations which constitute the disorders of the so-called "deterioration process," or *dementia præcox.* Unfinished or chronically sub-efficient action, a life apart from the wholesome influence of companionship and concrete test, and finally a progressive incongruity in meeting the inevitably complex demands of the higher instincts—this is practically the formula for the deterioration process.[1]

The following is Dr. Meyer's clinical description of a typical case:

She began school at seven years, was smart, and applied herself well, but at the age of eleven she seemed to be failing and was thought to be studying too hard. She grew thin, seemed nervous, and complained of headaches. At twelve she was in poor health. . . . [later] She was disappointed at home, for some time dreamt of becoming a teacher, but soon sank into hypochondriacal ruminations, and finally, at twenty-one, after useless operations, passed into a confused religious excitement, followed by stupor, in which she sits inactive and irresponsive, *with the top-heavy and yet empty notion of being good, of saving the world,* etc.

The next few decades may witness the complete demonstration that such cases can usually be saved by being taken early in hand and trained to more complete activity and appropriate self-objectification.

But, as already indicated, the importance of this principle of the sanifying influence of wholesome activity does not lie merely or chiefly in the insurance it offers against outright insanity. Sanity, be it remembered, is a relative term, and therefore the importance of manual training in this connection goes far beyond its prophylactic value as an insurance against admission to an insane hospital. In a sense no one is perfectly sane. A noted American psychologist, after making a careful inventory of his absurd crotchets, phobias and other mental extravagances, pronounces himself insane on at least seventeen different counts! It is doubtful whether many of us, if truly honest with ourselves, could make any better claim to perfect sanity. Just as there are millions of physically inefficient persons who are in no immediate danger of death, and relatively few who are perfect of body, so there are no end of people who are in no danger of trial for lunacy, but who nevertheless are decidedly below their own best level of mental balance. *Dementia præcox* has been mentioned at length only because it reveals, writ large, what to a less degree is true of most of us. The causes which

[1] Adolph Meyer, in the *Psychological Clinic,* 1908, pp. 96–97.

produce complete deterioration in the individual of nervous instability may, in the person of better hereditary endowment, result in nothing more serious than a temporary nervous break-down, "a slump of relative inactivity" (Meyer), or some other manifestation tending to rob life of its due zest and render success more difficult. To escape such dangers, every individual needs to be taught to "avail himself of the power of the concrete." We must find for every child the level where he can function successfully if we would have him escape the shocks of disappointment, the habits of failure and the resulting inactivity, day-dreaming, vain wishing and chasm between thinking and doing. It behooves us "to make doing just as attractive as knowing," and to explore ways and means of enlarging the child's opportunities for the accomplishment of simple, wholesome and enjoyable things. Every person can be taught to do something well and take pleasure in doing it, and the result will contribute much more to the person's own mental balance and to the welfare of the world in general than will a smouldering volcano of sentiment and frothy, but inactive desire.

WHAT MASTERPIECES OF GREEK SCULPTURE WERE KNOWN TO THE MEN OF THE RENAISSANCE? A CENSUS

By EDWARD S. HOLDEN

U. S MILITARY ACADEMY

SOME popular writers on the Renaissance give, and seek to give, the impression that the sculpture known to the Renaissance was pure, high Greek, and that these masterpieces set all Italy astir. Scholars know better, but most of us are not scholars.

All my life I have been bullied by statements of the sort, and at last the worm has turned and has consulted the scholars, as it should have done long ago. The following paragraphs will seem of very slight importance to the few students who know, but they may have some interest to others. If I—no scholar—knew where the data which I have here tabulated could be found collected, such paragraphs might well be quoted. But I do not know, and many others are probably as ignorant as I. It is for them and myself that I am writing, making every apology to the real scholars; and in partial excuse, asking them why I have not been able to find such tables as I here give in some handbook or manual.

Here follow a few quotations from writers on the fine arts of the Renaissance. All of them give the scholar's point of view. For brevity, I have sometimes ventured to summarize them.

> Whatever may be the facts of to-day, the eye of Europe in the middle ages was not accustomed to Greco-Roman forms in art. In Spain, France, Germany or Britain, the Roman ruins were even then so rare . . . that any knowledge of them . . . was out of question. In Italy, Roman ruins were no rarity, and in Rome they were abundant, but the idea of copying them never suggested itself to an Italian of the middle age. That antiquarian and historic interest in relics of the past, which is so natural to us, is an interest which dates from the Renaissance. To the middle age the ruin was a quarry; nothing more.[1]

How the interest in the literature of the ancients brought about a revival in the arts—architecture, painting, sculpture—need not be recited here. The story has been told a thousand times. One point may be emphasized, perhaps. The share of science in the revival has not been sufficiently recognized by most writers on the period. The name of Copernicus, for instance, is not mentioned in the index of any

[1] Goodyear, "Renaissance in Modern Art," p. 49.

standard work that I have seen excepting by Symonds.[2] Yet Copernicus came to Rome to study astronomy with a company of Roman doctors; the schools of Italy were then alive with inquiry. When he published his monumental book in 1543 he found a host of readers prepared to comprehend his theory of the world.

The interest in ancient art had its foundations in literature and archeology. Biondo's treatise on the monuments of ancient Italy was written before 1463. In 1462 Pius II. issued a bull protecting the remains of ancient Rome from further depredations. The Museum of the Vatican was founded by Julius II. (1503–13).

The appreciation of classical sculpture was quickened by the recovery of many ancient works. Many? Not many of high class. The Apollo Belvedere was set up by Pope Julius.

> Michel Angelo saw the Laocoön disinterred from the ruined Baths of Titus. Leo X. (1513–21) acquired the reclining statues of the Nile and the Tiber, and the so-called Antinoüs. These and other specimens of classical art, though not representative of that art at its best, helped to educate Italian taste, already well disposed towards every form of classical culture. The Latin verse-writers of Leo's age show the impression made by the newly found works of sculpture.
>
> It is more interesting to note the remark of an expert, the Florentine sculptor Ghiberti, who, in speaking of an ancient statue which he had seen at Rome, observes that its subtle perfection eludes the eye, and can be fully appreciated only by passing the hand over the surface of the marble.[3]

Ghiberti (died 1455?) made a collection of antique marbles, which was inherited by his grandson, and on the death of the latter sold and dispersed.[4]

Donatello (died 1466?) and Brunelleschi were known as "treasure-seekers" and they exhumed many fragments of cornices, capitals and bas-reliefs, coins and the like. Of these Donatello made drawings and studies, while Brunelleschi journeyed from Florence to Cortona to see a sarcophagus in the Duomo, of which Donatello had given him a glowing description.[5]

Michelangelo's introduction to Lorenzo de' Medici came about through a copy which the lad had made from the antique (the head of a Faun, now in the Uffizi) about 1489, and for three happy years Michelangelo lived and studied in the studio-garden among the examples of ancient statuary which the duke had brought together.

> The one antique fragment which seems to have roused his enthusiasm . . . was the Belvedere Torso. The Laocoön does not seem to have greatly moved him.[6]

[2] See "The Renaissance of Science," *The Popular Science Monthly*, November, 1903.

[3] Sir Richard Jebb in "Camb. Mod. Hist.," Vol. I.

[4] Perkins, "Tuscan Sculptors," I., p. 136.

[5] *Ibid.*, p. 139.

[6] *Ibid.*. Vol. II., p. 7.

Athens was in the possession of Italians from 1387 until it was captured by the Turks in 1458, and during that interval a few scholars visited the city. After 1450 all is darkness until 1674, when the Frenchman Jacques Carrey made his drawings of the Parthenon.

Its sculptures could hardly have been known to the men of the Renaissance. A few of the greatest statues were known to Michelangelo—the Torso of the Belvedere especially, and he declared himself its pupil. This figure was one of the chief promoters of the Renaissance in sculpture.[7]

> The especial reverence for classical antiquity, which in former times so exclusively prevailed, invested every fragment of ancient sculpture, even the most trivial, with a sentimental importance. . . . The antique had comparatively little to do with the truly great Italian school of sculpture of the fifteenth century. . . . External nature, religious feeling, human character and expression, these were alike the school, and in a far greater measure than the antique, the inspiring motives, of (Ghiberti, della Quercia, Donatello, Luca della Robbia, Verocchio and a long list of splendid names).[8]

Winckelmann's "History of Ancient Art" appeared in 1764, after long years of preparation. Pater says:

> It is since his time that many of the most significant examples of Greek art have been submitted to criticism. He had seen little or nothing of what we ascribe to the age of Pheidias; and his conception of Greek art tends, therefore, to put the mere elegance of the imperial society of ancient Rome in place of the severe and chastened grace of the *palæstra*. For the most part he had to penetrate to Greek art through copies, imitations, and later Roman art itself . . . a turbid medium.[9]

The foregoing extracts give the true doctrine. Roman art, not Greek, furnished the inspiration of the Renaissance sculptor, speaking generally. The tables that immediately follow furnish a striking proof.

Dates at which Seventy-six of the most Celebrated Statues were Found—Unearthed

A selection was made of seventy-six of the most famous statues of Greece, and from Mr. Edward Robinson's scholarly catalogue of the casts of the Boston Museum the dates at which these statues became known to the world were set down.

The little table follows:

[7] Robinson, Boston Museum Catalogue, p. 324.

[8] "Italian Sculpture of the Middle Ages," introduction by J. C. Robinson, superintendent of the art collections of the South Kensington Museum, London (1862).

[9] W. Pater, "Renaissance," p. 205.

FIFTEENTH CENTURY AND EARLIER

Statue	Now in	Unearthed in
Apollo Belvedere	Rome	fifteenth century?
Boy with thorn	Rome	before 1471
Venus—Medicean	Florence	(?) (Müntz)

SIXTEENTH CENTURY

Aphrodite (Knidian)	Rome	before 1700
"Dying Gladiator"	Rome	sixteenth century
Fighting Persian	Rome	1514
Laocoön	Rome	1506
Belvedere Torso	Rome	sixteenth century
Idolino	Florence	1530
Sleeping Ariadne	Rome	sixteenth century
Artemis—Versailles	Louvre	sixteenth century
"Germanicus"	Louvre	sixteenth century?
Arringatore	Florence	sixteenth century?
Wrestlers	Florence	1583
Hermes Belvedere	Rome	about 1542
Silenos and Dionysos	Louvre	sixteenth century
Niobe	Florence	1583
Ilioneus	Munich	1556–63
Niobid	Rome	sixteenth century

SEVENTEENTH CENTURY

Fighter of Agasias	Louvre	1605–21
Venus Genetrix	Louvre	about 1650
Faun—Barberini	Munich	1623–44
Ares resting	Rome	before 1633
Venus of Arles	Louvre	1651

EIGHTEENTH CENTURY

Discobolus of Myron	Rome	1791?
Pericles (?)—bust	British Museum	1781
Spear-bearer of Polykleitus	Naples	1797
Faun—Capitol	Rome	1701
Mercury resting	Naples	1758
Antinoüs	Rome	eighteenth century
Venus—Capitol	Rome	1752
Venus—Capua	Naples	1756
Venus—crouching	Rome	1760
Aktaion—attacked	British Museum	1774
Apollo with the lizard	Rome	1777
Zeus—Otricoli	Rome	end of century
Apollo with the lyre	Rome	1774
Clio	Rome	1774
Thalia	Rome	1774
Standing Discobolus	Rome	1792
Discobolus	British Museum	1791

NINETEENTH CENTURY

Harpy Tomb	British Museum	1838
Ludovisi Throne	Rome	1886
Herakles shooting	Munich	1811
Herakles and the apples of the Hesperides	Olympia	1876
Charioteer	Delphi	1896
Eleusinian Deities	Athens	1859
Amazon	Berlin	1868
Monument of Dexileos	Athens	1863
Hermes of Praxiteles	Olympia	1877
Hermes of Andros	Athens	1833
Charioteer (Mausoleum)	British Museum	1857
Mausolus	British Museum	1857
Demeter (Knidus)	British Museum	1858
Column-Drum (Ephesus)	British Museum	1871
Hypnos	British Museum	1855
Apoxyomenos	Rome	1849
Sophocles	Rome	about 1839
Winged Victory	Louvre	1863
Eubuleus (?)	Athens	1885
Venus of Melos	Louvre	1820
Battle of the gods and giants (Pergamon)	Berlin	1879–80
Diadumenos (Delos)	Athens	1894
"Athena thinking"	Athens	1888
Dancing Faun	Naples	1830
Warrior (Delos)	Athens	1882
Silenos	Athens	1862
Boxer resting	Rome	1885
Augustus Cæsar	Rome	1863
Young Apollo	Berlin	about 1880
Young Dionysos	Rome	1881
Nereids	British Museum	1838
Nike of Paionios	Olympia	1875
Apollo and the Omphalos	Athens	1862
Marsyas (after Myron)	Rome	1823
Venus—Esquilene	Rome	1874

It appears that of the seventy-six most famous monuments there were found:

In the fifteenth century or earlier	3 statues
In the sixteenth century	16 statues
In the seventeenth century	5 statues
In the eighteenth century	17 statues
In the nineteenth century	35 statues
Total	76 statues

The statistics of a list of *all* statues would not serve our purpose as well as this enumeration, which relates only to the most celebrated works. The men of the Renaissance knew barely a score of the great statues. Roman copies of Greek originals were known to them, and a few of the great originals themselves. But how few they were!

THE PROGRESS OF SCIENCE

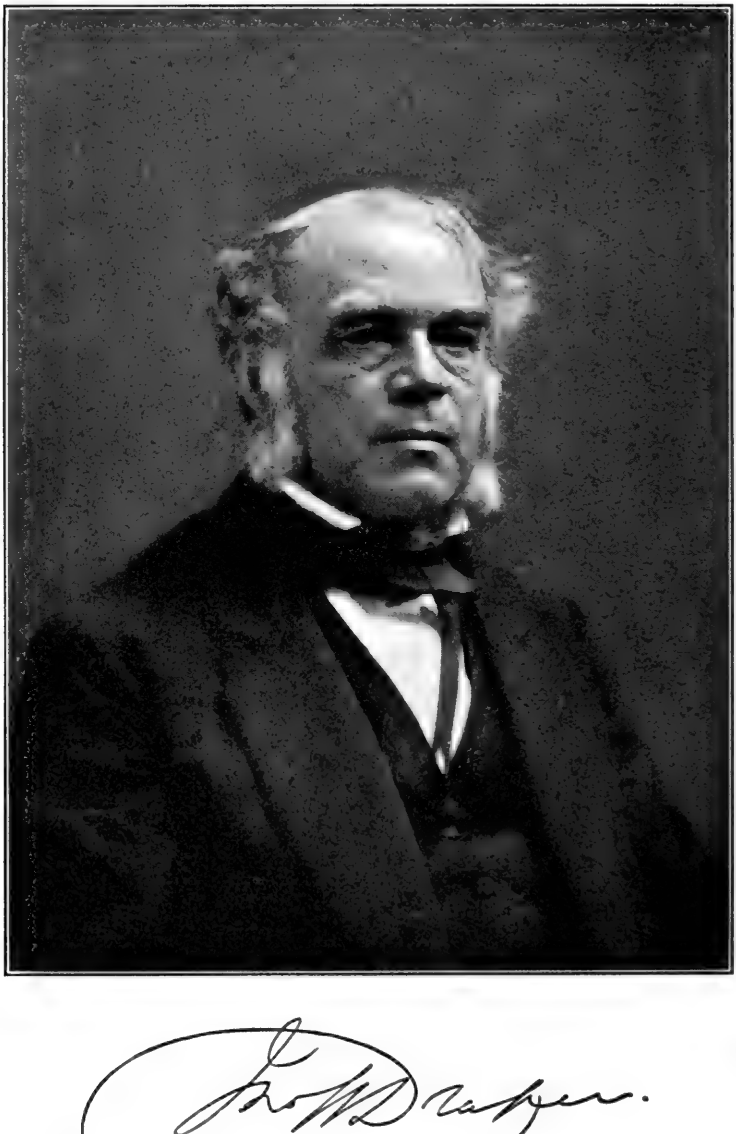
MEETINGS OF SCIENTIFIC SOCIETIES

APART from the Christmas holidays, the month of April is the favorite season for scientific meetings. It would be the best time in the year, if it were only possible for educational institutions to agree on a week's holiday. At present some of them have a vacation at a regular time, some follow Easter and some have none. There is now active discussion on the reform of the calendar. One month with twenty-eight days is certainly undesirable, and it would be convenient if each month began on the same day of the week. A radical reform is no more unlikely than any other, and the suggestion made by Professor T. C. Chamberlin (*Science*, November 25, 1910) is alluring. It is to have twelve months of 28 days with an extra week at the close of each quarter, Christmas week having an added day with another extra day on leap year. Southern nations may be over-fond of holidays, but life is almost too monotonous in the sober north. It might be well if each quarter were followed by a week in which the routine business of life were interrupted—Christmas week for family reunions, Easter week for religious and scientific gatherings, Julien week for national and international celebrations, the autumn week for harvest and labor festivals. While we wait, probably in vain, for such a reform, educational institutions might, and to a certain extent have adopted the plan of four quarters with a week's intermission. Concentrated effort might give us a week in the spring for scientific meetings.

The National Academy of Sciences holds its annual stated meeting in Washington, beginning on the third Tuesday in April, and almost justifies its existence by the time of meeting, as members from further north are likely then to come into the fullness of the spring. The academy is in the main of interest to its limited membership. It is possible that the honor of election stimulates to scientific research, though it can scarcely be so effective in this direction as would be the case if the work of the academy were better known and if there were some more tangible advantage in membership, as is the case in some of the continental academies, where the members receive salaries from the government. If research is to be accomplished it must be paid for in some way, and there is much to be said for the endowment of individuals through an institution such as the National Academy of Sciences.

At present the official function of the academy as the scientific adviser of the government is hardly exercised. Indeed it is not clear how it could be to advantage when the government has in its own employment hundreds of scientific men. Nor can it be said that the programs of scientific papers are of great interest. Important research work is presented each year, but probably not more important than before the special scientific societies, and it has now become very difficult for scientific work in all directions to be presented before a single group of individuals.

Following the meeting of the National Academy in Washington, the American Philosophical Society of Philadelphia has in recent years arranged a meeting which has assumed national importance. The program of scientific papers is larger than at Washington, the society is fortunate in


Jno W Draper.

having its own historic building for its meetings, and the city is generous in its hospitality. The papers presented are of the same high standing and the same mixed character as at Washington.

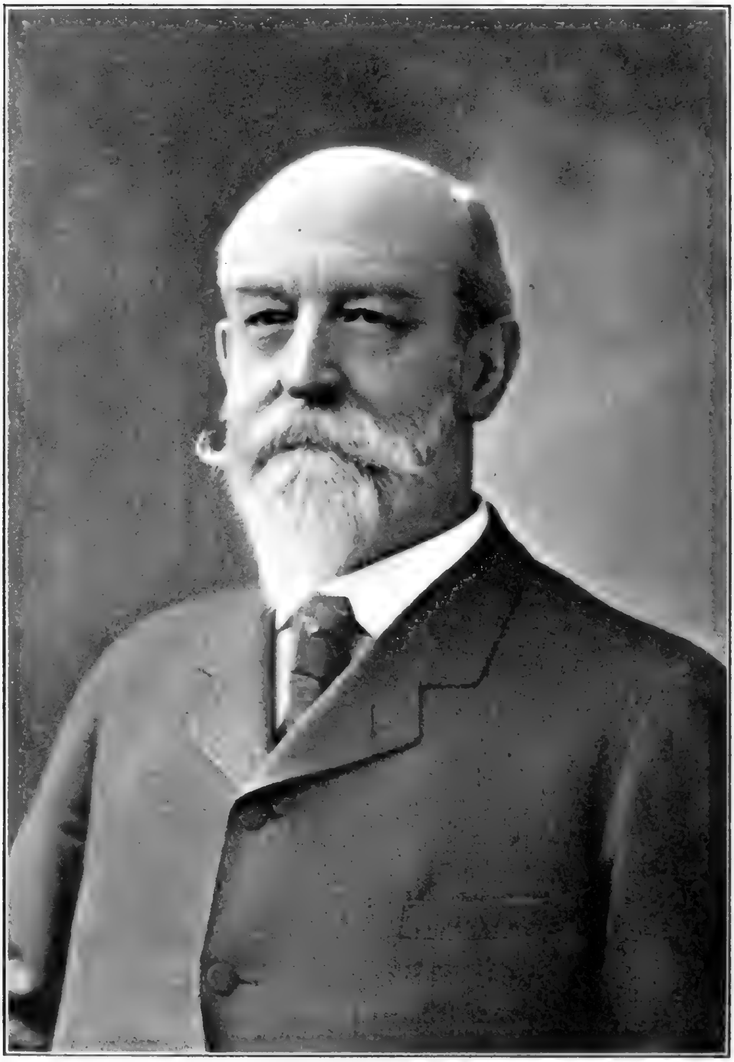
The spring is also the time chosen for the meetings of some of the state academies of science. A glance at the program of one of these, such as the Michigan Academy of Sciences, shows that it contains an almost bewildering array of papers. These are, however, presented before several sections and thus have a more homogeneous attendance and better chance for discussion. An interesting event this year was the joint meeting of the different scientific and learned societies of California, which will doubtless hereafter become an annual event on the Pacific coast.

THE CENTENARY OF THE BIRTH OF JOHN WILLIAM DRAPER

The centenary of the birth of John William Draper, which occurred on the fifth of May, was celebrated with adequate ceremonies and addresses by New York University, where he was professor from 1837 until his death in 1882, and where two of his sons were also professors.

Draper was the son of an English Wesleyan clergyman. He came to America at the age of twenty-one, and graduated as doctor of medicine from the University of Pennsylvania in 1836. His work covered a wide field. He made important researches in chemistry, physics and physiology. He wrote text-books and taught these subjects, being a leader in medical education. He took an important part in the development of two of the most important advances of applied science—electrical telegraphy and photography. Later he turned his attention to philosophical and historical subjects. His history of the intellectual development of Europe and his history of the conflict between religion and science have been widely read and are of great

Autotype Copy of the Earliest Sunlight Picture of a Human Face.
Miss Dorothy Catherine Draper, taken by her brother, Professor John William Draper, M.D., LL.D., early in 1840. The original daguerreotype is the property of Sir William John Herschel.



Henry Pickering Bowditch.

influence, having appeared in many editions and having been translated into a dozen different languages. Finally he devoted ten years of his life to a history of the American civil war.

Draper's early scientific work was concerned with the chemical action of light. In 1837 he investigated the growth of plants exposed to the light of the solar spectrum. He at that time also studied the action of light in changing the color of metallic salts and applied the photographic process to the solution of physical problems. When Daguerre's discovery was announced he improved the process and took in 1840 the first portrait of the human face, at a time when this was regarded as impossible in Europe. In the same year he took the first photograph of the surface of the moon. Draper was also the first to obtain photographs of the diffraction spectrum, and of the ultra-red and ultra-violet lines. In 1857 he wrote that the occurrence of lines in the spectrum is connected with the chemical nature of the substance and that "if we are ever able to acquire certain knowledge respecting the physical state of the sun and other stars, it will be by an examination of the light they emit." It is an interestitng fact that his son, Henry Draper, in 1872, was the first to obtain photographs of the fixed lines in the spectra of stars.

Draper's work in physiology was of importance; he made many new discoveries and consistently used physico-chemical explanation in the place of the vitalism of those days. In like manner he applied causal principles to the evolution of society. Draper played an important part in the development of modern science at a time when America was represented by but few leaders.

HENRY PICKERING BOWDITCH

Henry Pickering Bowditch was a member of one of those families which in Boston and in Philadelphia have maintained the traditions of the English aristocracy. His grandfather was the eminent mathematician, Nathaniel Bowditch, and his father and his brothers have like himself always been ready in the performance of public service. Bowditch was born in Boston in 1840; on graduating from Harvard College in 1861 he volunteered for service in the civil war, and at its close retired as major of the Fifth Massachusetts Cavalry. He then passed through the Lawrence Scientific School and the Harvard Medical School and spent three years abroad working under Carl Ludwig at Leipzig. When he returned to Boston in 1871 the chair of anatomy and physiology held by Oliver Wendell Holmes was divided, physiology being assigned to Bowditch. For thirty-five years he was a leader in education and research in the medical sciences, and the physiological laboratory that he founded was the pioneer of laboratories in the medical sciences. He was largely responsible for the medical school building, completed in 1883, the laboratories of which were admirably equipped for that time, and again was largely responsible for the magnificent buildings and laboratories of the new medical school opened in 1906, the year in which, owing to failing health, he became professor emeritus. As dean of the medical school and in other ways he exercised an enormous influence on the improvement of medical education and medical science in this country. His own researches on the growth of children, on vision, on the knee jerk and on other subjects were of great importance, but in a brief biographical notice, it seems more fitting to dwell on his great public services for physiology, for medical education, for the city and for the country. Of his personality Professor Charles S. Minot, a student under him and for many years his colleague, says: "He found great happiness in his home life, in his children and grandchildren, and also in the numerous friends, whom he attached not only by his unusual abilities but by his personal charm. He was social by nature, keenly humorous, warm and faithful in his attachments, full of the zest of life. He was profoundly modest and seemed never to know how high his abilities were estimated by others. He never quarrelled, but was for every good cause he championed a good fighter. Perhaps his most distinguishing trait was his remarkable combination of keen practical sense in the use of means with enthusiasm in the pursuit of ideal aims. With all his buoyant vitality, with all his eager interest in men and affairs, he was essentially an idealist, who won the love and admiration of many friends both in Europe and America.''

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. Herman Knapp, professor emeritus of ophthalmology in Columbia University; of Dr. Charles Stedman Bull, professor of ophthalmology in the medical department of Cornell University; of Mr. T. Rupert Jones, F.R.S., formerly professor of geology at Sandhurst; of Major George Lamb, director of the Pasteur Institute of India, and of Dr. Pehr Olsson-Seffer, botanist of the Mexican government, murdered by brigands in the Mexican insurrection.

At the meeting of the National Academy of Sciences on April 20, the following were elected to membership: Edward Emerson Barnard, astronomer, Yerkes Observatory, Williams Bay, Wis.; Edward Burr Van Vleck, professor of mathematics, University of Wisconsin; John Filmore Hayford, director of the College of Engineering, Northwestern University; Edwin Herbert Hall, professor of physics, Harvard University; Julius Oscar Steiglitz, professor of chemistry, University of Chicago; Bertram Borden Boltwood, professor of radio-chemistry, Yale University; James Furman Kemp, professor of geology, Columbia University; Arthur Louis Day, director of the Geophysical Laboratory of the Carnegie Institution; Robert Almer Harper, professor of botany at the University of Wisconsin. Foreign associates were elected as follows: Professor Ernest Rutherford, University of Manchester, England; Professor Vito Volterra, University of Rome, Italy. At the annual dinner of the academy on April 19 the Draper Gold Medal was presented to Mr. C. G. Abbot, of the Smithsonian Institution, for his researches on the infra-red region of the solar spectrum and his accurate measurements, by improved devices, of the solar ''constant'' of radiation.

Sir J. J. Thomson, Cavendish professor of experimental physics in the University of Cambridge, and Dr. D. Hilbert, professor of mathematics at Göttingen, have been elected corresponding members of the Paris Academy of Sciences.

Dr. Frederic A. Lucas, curator in chief of the Museum of the Brooklyn Institute, and formerly curator of the U. S. National Museum, has been elected director of the American Museum of Natural History.—Dr. Elmer Ellsworth Brown, U. S. Commissioner of Education, has been elected chancellor of New York University.

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